THE FUTURE WATER SUPPLY OF SAN FRANCISCO

FROM THE

Conservation and Use of its Present Resources

THE SPRING VALLEY WATER COMPANY

SAN FRANCISCO

THE FUTURE WATER SUPPLY OF SAN FRANCISCO

THE WATER SUPPLY OF SAN FRANCISCO.

137 Square Miles Owned for Water Supply Within a Radius of 50 Miles of San Francisco.

THE

FUTURE WATER SUPPLY

OF

SAN FRANCISCO

A REPORT TO

THE HONORABLE THE SECRETARY OF THE INTERIOR AND THE ADVISORY BOARD OF ENGINEERS OF THE UNITED STATES ARMY

BY THE

SPRING VALLEY WATER COMPANY

SAN FRANCISCO, CALIFORNIA.

October 31, 1912.

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ON THE

SAFE, DEPENDABLE YIELD AND AVAILABILITY OF THE RESOURCES OF THE SPRING VALLEY WATER COMPANY

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EXECUTIVE DEPARTMENT

SPRING VALLEY WATER COMPANY

375 Sutter Street

SAN FRANCISCO, CAL., October 31, 1912.

The Honorable, the Secretary of the Interior,
and the Advisory Board of Engineers
of the United States Army,
Washington, D. C.

Sirs:

In accordance with a letter from the Secretary of the Interior, dated May 28, 1912, the Spring Valley Water Company herewith presents the following reports bearing upon the adequacy of its property for furnishing San Francisco with an ample supply of water in the future, namely, by:—

Mr. Hermann Schussler, Consulting Engineer, and Mr. F. C. Herrmann, Chief Engineer, of the Spring Valley Water Company; Mr. George G. Anderson, Hydraulic Engineer of Denver, Colorado; Messrs. Wm. Mulholland and J. B. Lippincott of Los Angeles, Chief Engineer and Assistant Chief Engineer of the Los Angeles Aqueduct; Prof. J. N. Le Conte, Hydraulic Engineer of the University of California; Dr. J. C. Branner, Vice-President and head of the Department of Geology of Stanford University; Dr. A. C. Lawson, head of the Department of Geology of the University of California; Mr. F. W. Roeding, Manager of Agriculture for the Company, and formerly Irrigation Manager of the Irrigation and Drainage Investigations of the Pacific Division, U. S. Dept. of Agriculture; and appendices of Mr. C. H. Lee, of the U. S. G. S., and Messrs. J. J. Sharon, T. W. Espy, I. E. Flaa and H. Monett, Assistant Engineers of the Company.

In another volume is presented a report by Gen. H. M. Chittenden of Seattle, who was assisted by Mr. A. O. Powell, C. E., of Seattle, which is the result of a review of the above reports, study of other data bearing upon the subject, and an investigation of conditions on the ground.

These reports are herewith submitted for your consideration.

Respectfully,

S. P. EASTMAN,
Vice President & Manager
Spring Valley Water Company

RECAPITULATION

COMPARISON

Determinations of Safe Dependable Yield

Resources of the Water Supply of San Francisco

PENINSULA SYSTEM:	Herrmann. M. G. D.	Anderson. M. G. D.	Schussler. M. G. D.	Mullholland-Lippincott. M. G. D.	Chittenden-Powell. M. G. D.
Developed—					
Pilarcitos and San Andreas; Crystal Springs	19.50	19.02	19.00	.....	19.50
Lake Merced	3.50	2.80	3.00	.....	.....
Undeveloped—					
Coast streams; West Union	51.20	.....	50.00	.....	50.00
West Union		.....	.....	....	.....
Ravenswood and Alviso Wells	21.00	.....	21.00	.....	20.00
Total of Peninsula	95.20	.....	93.00	.....	89.50
ALAMEDA SYSTEM:					
Calaveras	60.14	57.00	58.0	.....	....
Upper Alameda			10.0		
Accumulated surplus	.....	9.48	...	.....	.....
San Antonio	8.92	8.50	15.66	.....	†90.00
Sunol Drainage	11.36	7.40			
Arroyo Valle	55.38	18.00	30.00	51.50	40.00
Livermore Valley		30.00	17.6		
Evaporation	...	12.00	.....	.....	....
Total of Alameda System	135.80	‡142.38	*131.26 *130.00	.....	130.00
GRAND TOTAL	**§231.00**	.....	***223.00**	.....	**219.50**

*Mr. Schussler's net yield from the Alameda System, using 23 years' records and allowing 10 M. G. D. evaporation from Livermore Valley, is 130 M. G. D. Using records for 19 years he obtained 131.26 M. G. D. gross run-off. Adding to his net figure the yield of Coyote River (21 M. G. D.) and Gilroy artesian basin (14 M. G. D.), he obtains a total safe yield of 258 M. G. D.

†Calaveras, Arroyo Valle and San Antonio Reservoirs.

‡Mr. Anderson's net yield from the Alameda System was 142.38 M. G. D., from which he deducted 2 M. G. D. for local use, leaving available a yield of 140.38 M. G. D. for San Francisco. He did not finish his calculations in time to be used in this report as to the yield of the Coast Streams Region, but he did find that they gave ample evidence of great productivity.

§To Mr. Herrmann's total of 231 M. G. D. there should be added 21 M. G. D. (Coyote System), making the net total for the entire system 252 M. G. D.

Mullholland and Lippincott did not make detailed calculations of remainder of the Alameda System, but studied and reviewed the Herrmann report on the Alameda System, and gave it their endorsement.

Note: The Chittenden and Powell reports were filed with the Advisory Board of Army Engineers in San Francisco, Cal., on November 1, 1912, independent of this report.

REPORT

ON THE

SAFE, DEPENDABLE YIELD AND AVAILABILITY OF THE RESOURCES OF THE SPRING VALLEY WATER COMPANY

Letter of Transmittal

San Francisco, Cal., October 31, 1912.

S. P. Eastman, Esq.,
Vice President and Manager,
Spring Valley Water Company.

Dear Sir:—In compliance with your request, I beg to submit herewith a report on the water supply of San Francisco, showing the safe, dependable yield of the resources of the Spring Valley Water Company, particularly for future supply.

In the preparation of the report I have frequently consulted with Dr. J. C. Branner, of Stanford University, and with Dr. A. C. Lawson, of the University of California, on questions of geology; with Mr. Hermann Schussler, who conceived and constructed the works of the Spring Valley Water Company; with Messrs. Mulholland and Lippincott, consulting engineers, on the problems of underground waters, and with Mr. George G. Anderson, consulting engineer, on questions of rainfall and run-off. To these gentlemen I acknowledge my grateful appreciation for valuable advice and assistance.

To the members of the engineering corps of the Spring Valley Water Company, I wish to express my gratitude for faithful and loyal services in the preparation of this report, covering a period of many months.

Yours very truly,
F. C. HERRMANN,
Chief Engineer.

THE FUTURE WATER SUPPLY OF SAN FRANCISCO, CALIFORNIA

REPORT

ON THE

SAFE DEPENDABLE YIELD AND AVAILABILITY OF THE RESOURCES OF THE SPRING VALLEY WATER COMPANY

BY

F. C. Herrmann,
Chief Engineer, Spring Valley Water Company,
October 1st, 1912.

There Will be Enough Water for San Francisco Until Beginning of Next Century.

The purpose of this report is to present an estimate of the safe dependable amount of water that may be delivered daily to the people of San Francisco by the complete and intelligent development of the present resources of the Spring Valley Water Company, and to determine at what time in the remote future additional water supply must be obtained elsewhere.

These resources extend over large areas adjacent to the region of San Francisco Bay, and although the most important of these will be operated in harmony, each assisting the other to the best advantage, they are divided into the following component parts for the purpose of analysis in this report:

Peninsula System—		
Bay Slope	Nearly complete...	35 sq. mi.
Coast Streams	Reserved for future supply	65 sq. mi.
Alameda System	Partially developed	620 sq. mi.
Coyote System	Reserved for future supply	115 sq. mi.
Alviso-Ravenswood Wells	Partially developed.	subterranean
Lake Merced	Nearly complete...	"

The Spring Valley Water Company has secured water resources for the people of San Francisco that when completely developed will safely produee year in and year out 210 M. G. D., or over five and one-half times the present needs of the City. In addition to this, other sources have been secured, which may be depended upon to supply 42 M. G. D., for use within the proposed metropolitan district, making a grand total of 252 M. G. D., as follows.

	M. G. D.	M. G. D.
For the City of San Francisco		
Peninsula System—		
Crystal Springs, San Andreas and Pilarcitos Reservoirs, as at present developed	**19.5**	
Additions from Coast Streams and West Union Creek	**51.2**	
Lake Merced	**3.5**	
Total		**74.20**
Alameda System—		
Calaveras	**60.14**	
San Antonio	**8.92**	
Sunol Gravels	**11.36**	
Arroyo Valle and Livermore Gravels	**55.38**	**135.80**
Total		**210.00**
Additional for Metropolitan District—		
Coyote System	**21.00**	
Alviso and Ravenswood	**21.00**	**42.00**
Grand Total		**252.00**

THE STONE DAM ON PILARCITOS CREEK.
Constructed in 1871 to Conserve the Overflow and Waters Down Stream from Pilarcitos Reservoir, which are Led to San Andreas. The Region One of Surpassing Beauty.

Making the liberal allowance of 100 gallons per day per inhabitant, the 210 M. G. D. available for the City of San Francisco is sufficient to serve a population of over 2,000,000 people. The average of the curves of future population made within recent years by Hermann Schussler, Prof. C. D. Marx, C. E. Grunsky, E. H. Hopson and Marsden Manson indicates that this figure will be reached about the beginning of the next century.

Utilizing the 252 M. G. D., together with other available local sources of supply, and applying the same rate of per capita consumption of 100 gallons per day to the population curve on page 76 of the report of John R. Freeman on the Hetch Hetchy Water Supply, the Metropolitan District of San Francisco may be served from local sources of supply well into the next century.

One great factor in the value of these sources of supply is the large aggregate storage located at the door of the City. The *surface storages* are enumerated as follows:

	M. G. Ultimate.
Peninsula System—15 miles from S. F.	102,500
Alameda System —35 " " "	80,504
Coyote System —63 " " "	9,100
Total Surface Storage	192,104

If no rain whatever fell for over 14 years, this storage would be sufficient to care for the present needs of the City during that time.

Spring Valley Storage Greater than Tuolumne System.

Better to realize the great extent of this storage, comparison is made with the total ultimate storage of the proposed reservoirs on the Tuolumne River and its tributaries, as follows:

Spring Valley Water Company Reservoirs	192,104	M. G.
Tuolumne River Reservoirs	165,500	"
Excess in favor of Spring Valley Water Company	26,604	"

Extensive underground storage, which is the source of subterranean waters at Pleasanton, Sunol, Alviso and Ravenswood, is not included in the above, and in the aggregate furnishes storage in excess of the enormous storage of the surface reservoirs.

Basis of Report.

Available physical data relevant to the problem in hand, together with careful and extended field investigations, form the basis of this report. The data consist of:

(a) Rainfall records, both public and private, covering the territory from San Francisco to Gilroy, and from the Pacific Ocean to San Joaquin Valley.

(b) Run-off measurements at various points on these systems, some of them covering long periods of time and others but very short periods.

(c) Maps, records, surveys, extensive statistical data and studies of the Spring Valley Water Company.

(d) Extensive reports by most of prominent engineers and geologists, dealing with the hydrology and geology of this region.

(e) Maps and publications of the United States Government.

Spring Valley Has Made Many Gagings Over Long Periods.

Gagings have been made in the various streams which are included in the resources of the Spring Valley Water Company, some of which go back for over 40 years. It is to be regretted that many of these were destroyed in the conflagration of 1906. Those that escaped destruction and are available at the present time are tabulated in million gallons as follows:

	PENINSULA.				ALAMEDA SYSTEM.				
Season.	Crystal Springs Reservoir.	San Andreas and Pilarcitos.	Pescadero Creek.	Alameda Creek.	Calaveras Creek.	Upper Alameda Creek.	San Antonio Creek.	Arroyo Valle Creek.	Coyote Creek.
1887-88.......	.....	2,384	.....	.....	.....	.....	.....	.....	.....
1888-89.......	.....	2,516	.....	.....	.....	.....	.....	.....	.....
1889-90.......	15,786	7,159	.....	165,907	.....	.....	.....	.....	.....
1890-91.......	3,183	1,869	.....	38,931	.....	.....	.....	.....	.....
1891-92.......	780	1,249	.....	20,905	.....	.....	.....	.....	.....
1892-93.......	6,598	3,091	.....	117,511	.....	.....	.....	.....	.....
1893-94.......	4,045	2,604	.....	59,202	.....	.....	.....	.....	.....
1894-95.......	7,722	3,668	.....	86,422	.....	.....	.....	.....	.....
1895-96.......	2,164	2,261	.....	39,967	.....	.....	.....	.....	.....
1896-97.......	2,809	3,736	.....	67,772	.....	.....	.....	.....	.....
1897-98.......	1,490	548	.....	4,498	.....	.....	.....	.....	.....
1898-99.......	1,427	1,635	*1,998	23,091	13,720	.....	.....	.....	.....
1899-00.......	1,812	3,937	2,655	19,085	14,560	.....	.....	.....	.....
1900-01.......	981	3,138	9,179	40,038	20,531	.....	.....	.....	.....
1901-02.......	823	3,226	5,659	30,861	13,391	.....	.....	.....	.....
1902-03.......	2,469	4,460	4,507	37,854	15,471	.....	.....	.....	27,070
1903-04.......	5,108	5,399	9,743	36,464	19,380	.....	.....	.....	11,611
1904-05.......	2,261	3,995	7,395	20,451	14,902	.....	.....	4,247	10,396
1905-06.......	3,356	3,336	* 720	67,087	26,962	.....	† 3,147	16,881	37,928
1906-07.......	6,226	6,604	.....	104,856	37,146	.....	.....	31,793	66,517
1907-08.......	1,102	2,487	.....	20,703	9,203	.....	.....	3,372	15,442
1908-09.......	7,185	6,144	.....	75,844	.....	.....	.....	.....	57,637
1909-10.......	1,327	3,020	.....	32,536	.....	.....	.....	.....	.....
1910-11.......	7,483	4,721	.....	92,425	29,700	.....	.....	.....	.....
1911-12.......	734	949	.....	10,937	5,554	1,382	454	.....	.....

*Record for one-half season only.

†Flood records during three months only.

Note: The quantities given for the Crystal Springs, San Andreas and Pilarcitos Reservoirs are quantities measured in the reservoirs, and represent the net yield after deduction has been made for evaporation, while all other quantities represent measured run-off at the various gaging stations.

For the developed portions of the resources of the Spring Valley Water Company long records of actual volumetric measurements are available. The compilation of these gives directly their performance during a period of many years and without question their safe dependable yield.

Conclusions as to dependable yield from the Alameda System, the Coast Streams as an integral part of the Peninsula System, and the Coyote System have been drawn from careful and detailed analysis of available rainfall and run-off data, the deductions being based upon sound scientific principles.

Estimates of the dependable yield of the Alviso and Ravenwood wells have been taken from reports by Mr. Hermann Schussler, who created the works of the Spring Valley Water Company, and who as its Chief Engineer for many years made the study of its resources his life's work. Mr. Schussler is always conservative in his estimates of water production, and by reason of his long experience, intimate knowledge, and painstaking investigations of these resources, is considered the most competent man alive to judge the amount of water that may safely be withdrawn from the sources in question.

In this report, analyses have been made in the following order:

Peninsula System.
- Developed.
- Undeveloped.

Alameda System.

Coyote System.

The computations of drafts are expressed to second place decimals to obtain uniformity and to prevent confusion by rounding them off. It is not intended to convey the idea that these quantities can be determined with this degree of precision.

PENINSULA SYSTEM.

The Peninsula System lies directly south of and adjoining San Francisco within that range of mountains separating San Francisco Bay from the Pacific Ocean, and terminating abruptly at the Golden Gate.

This system is logically divided into two parts, the developed and the undeveloped.

The Developed Portion of the Peninsula System Will Safely Yield Twenty-three Million Gallons Daily.

The developed part consists of Lake Merced,

lying wholly within the City limits of San Francisco, the Crystal Springs and the San Andreas and Pilarcitos Reservoirs, lying from 7 to 17 miles south of the City. The catchment area of the last named reservoirs contains 35 square miles of mountains, culminating on the north in Peak Mountain (1900 feet elevation) and on the south in Sierra Morena (2400 feet elevation).

These mountains are covered with a very dense growth of trees and shrubs and are subject to an average annual rainfall ranging from 36 inches to 52 inches.

By reason of this very high rainfall the catchment areas of the Peninsula System have proved to be exceedingly good water producers. Practically the entire catchment area is owned in fee by the Spring Valley Water Company, thereby insuring water of the highest purity. Great skill and ingenuity have been displayed in this development, whereby wide latitude is given the operation of interchanging the waters of the three reservoirs and of permitting one reservoir to assist the others in storing any surplus.

At the present time the developed storage is nearly large enough to care for the entire run-off of the catchment area, except in the seasons of excessive rainfall. Additional storage of 40,000 M. G. may be obtained by increasing the height of the great Crystal Springs Dam, which was provided for when the dam was constructed.

The elevations and storage capacities of the constructed reservoirs of the Peninsula System are as follows:

	Present.		Future.	
Reservoir—	Capacity, M. G.	Elevation, Feet.	Capacity, M. G.	Elevation, Feet.
Crystal Springs......	23,000	283	63,000	337
San Andreas.........	6,000	440	6,000	440
Pilarcitos	1,000	692	1,000	692
Lake Merced.........	2,500	19	2,500	19

By reason of the strategic position of Lake Merced, lying wholly within the City limits of San Francisco and completely protected from contamination, its value in case of war or catastrophe is beyond the expression of figures.

It is seen that all of the other reservoirs deliver water into San Francisco by gravity.

Measurements covering a period of 45 years show the following safe net drafts from these sources:

Crystal Springs Reservoir..............	9½	M. G. D.
San Andreas and Pilarcitos............	10	"
Lake Merced	3½	"
Total	23	"

Undeveloped Portion of Peninsula System.

The undeveloped part of the Peninsula System is usually referred to as the "Coast Streams," though it also includes that portion of the catchment area of West Union Creek lying just south of the Crystal Springs Reservoir.

In developing the Coast Streams it is proposed to intercept the waters of the upper Pescadero and San Gregorio Creeks, at such an elevation that they will flow by gravity into the Crystal Springs Reservoir through a tunnel eleven miles long and with a capacity of one hundred million gallons daily.

The waters of those streams, which will be contributed below the gravity diversion, will be intercepted by the Pescadero Reservoir, having a storage capacity of 30,000 M. G., with a dam 300 feet high. (See Plate G-4.)*

The waters so stored will be pumped into Crystal Springs Reservoir through the tunnel above mentioned. The location of the component parts of the Coast Streams project in its relation to the developed part of the Peninsula System, is shown on Plate G-1.

Many Engineers Have Reported Favorably on Coast Streams.

The Coast Streams project as a future water supply to San Francisco has been under consideration since 1869, since when it has been very favorably reported upon by the following eminent engineers, who were not connected with the Spring Valley Water Company:

*Wherever numbered maps, diagrams or plates are mentioned in this report they refer to and are contained herein, and wherever maps, diagrams or plates are mentioned by number prefixed by a letter they refer to maps, diagrams, or plates in the appendix bearing the prefixed letter.

1869-71	Prof. Geo. Davidson, U. S. C. & G. S............	90 30	M. G. D. in wet years. M. G. D. in dry years.
1871	Gen. B. S. Alexander, U. S. Army Engineers....	47½	M. G. D.
1875	Mr. T. R. Scowden, Hydraulic Engineer........	58	M. G. D.
1877	Col. Geo. H. Mendell, U. S. Army Engineers....	15	M. G. D. {Gravity supply only. No storage in Pescadero.
1886	Mr. J. P. Campbell, Civil Engineer............	60	M. G. D.
1908	Mr. C. E. Grunsky, Hydraulic Engineer....	20	M. G. D. {Gravity supply only. No storage in Pescadero.

ON PESCADERO CREEK.
A Station for the Measurement of This Stream was Established in 1886 and Accurate Record Kept Until the Fire of 1906.

Throughout this period, Mr. Hermann Schussler investigated the Coast Streams in detail, establishing gaging stations on the streams as early as 1865. From these records Mr. Schussler estimated that by the use of storage in the Pescadero Reservoir the streams would support a draft of 50 M. G. D. Unfortunately some of these records were destroyed in the conflagration of 1906; those now available are:

(a) Rainfall at Camp Howard on Pescadero Creek for seventeen years from 1889 to 1906, and (b) run-off of the Pescadero at the same place for the two years 1887 to 1889 and for the six full seasons, 1899-90 to 1904-5. Camp Howard is located on Pescadero Creek just above the mouth of Peters Fork. These seventeen years of rainfall record show an average annual precipitation of 54.55 inches.

Above Camp Howard the Pescadero has a catchment area of 16 square miles. The average run-off at Camp Howard for the six seasons' record was 17.85 M. G. D., or an average of about 1,115,000 gallons per square mile per day.

Large Flow of Water in Coast Stream Country.

Comparing the water product of this catchment area with the combined catchment areas of the Pilarcitos and the San Andreas Reservoirs for the same six seasons we find that with a catchment area of 13.7 square miles the Pilarcitos and San Andreas watersheds furnished an average of 11.03 M. G. D., or an average rate of 805,000 gallons per square mile per day.

It is to be noted that the period covered by this six seasons' run-off record is wholly within the extraordinary cycle of eight dry seasons, 1898-99 to 1904-05, which was experienced all over the Pacific Slope, and which is fully discussed in another part of this report.

The catchment area of the "Coast Streams" is one of consistently high rainfall and run-off, and is well covered with a virgin forest of firs and redwoods. Being on the ocean side of the mountain range, the temperature even in midsummer is cool, and the weather damp and foggy. These several factors combine to regulate the rate of run-off, and produce a marked increase in the summer flow. Therefore, the conditions for diversion of the Coast Streams are exceedingly favorable.

In addition to the Camp Howard precipitation record, other records at Boulder Creek, Pilarcitos and along the Pacific Ocean are available and have been used in the study of the water yield from the Coast Streams area. All these records show this area to be one of very high rainfall.

Detailed analysis of the Coast Streams project is given in Appendix G, which has been prepared by Mr. I. E. Flaa, Assistant Engineer in charge of the headquarters division of the Spring Valley Water Company Engineering Department. Aside from his experience with the complex hydraulic problems of this Company, Mr. Flaa has had extended and valuable experience as Designing Engineer for the Pacific Gas and Electric Company in their large hydraulic developments in the Sierra Nevada Mountains.

How Coast Streams Will Be Developed.

Although the tunnel piercing the backbone of the Peninsula through which the waters from the Coast Streams will be conducted to the Crystal Springs Reservoir will have a capacity of 100 M. G. D., it is planned that the maximum flow by gravity to it will be 70 M. G. D., thereby leaving an excess capacity of 30 M. G. D. that may be utilized by the pumps at Pescadero Reservoir during the period of maximum gravity flow, which is estimated at two months per season. For the remaining ten months much more than this 30 M. G. D. capacity is available for pumped water.

Run-off from the upper reaches of the watersheds in excess of 70 M. G. D., together with the run-off of the lower reaches of the same streams, will be intercepted by the Pescadero Reservoir, and pumped back to the tunnel.

The Pescadero Reservoir thus becomes in reality a large regulating reservoir, the withdrawal from which will vary at such rates as the character of the season and good management demand. In this manner the Coast Streams project becomes one of the component parts of and tributary to the Crystal Springs Reservoir.

For the purpose of this report we have assumed a maximum working pumping capacity of 50 M. G. D., with an additional spare unit of 25 M. G. D. Thus in times of flood, estimated to cover sixty days per season, the rate of pumping

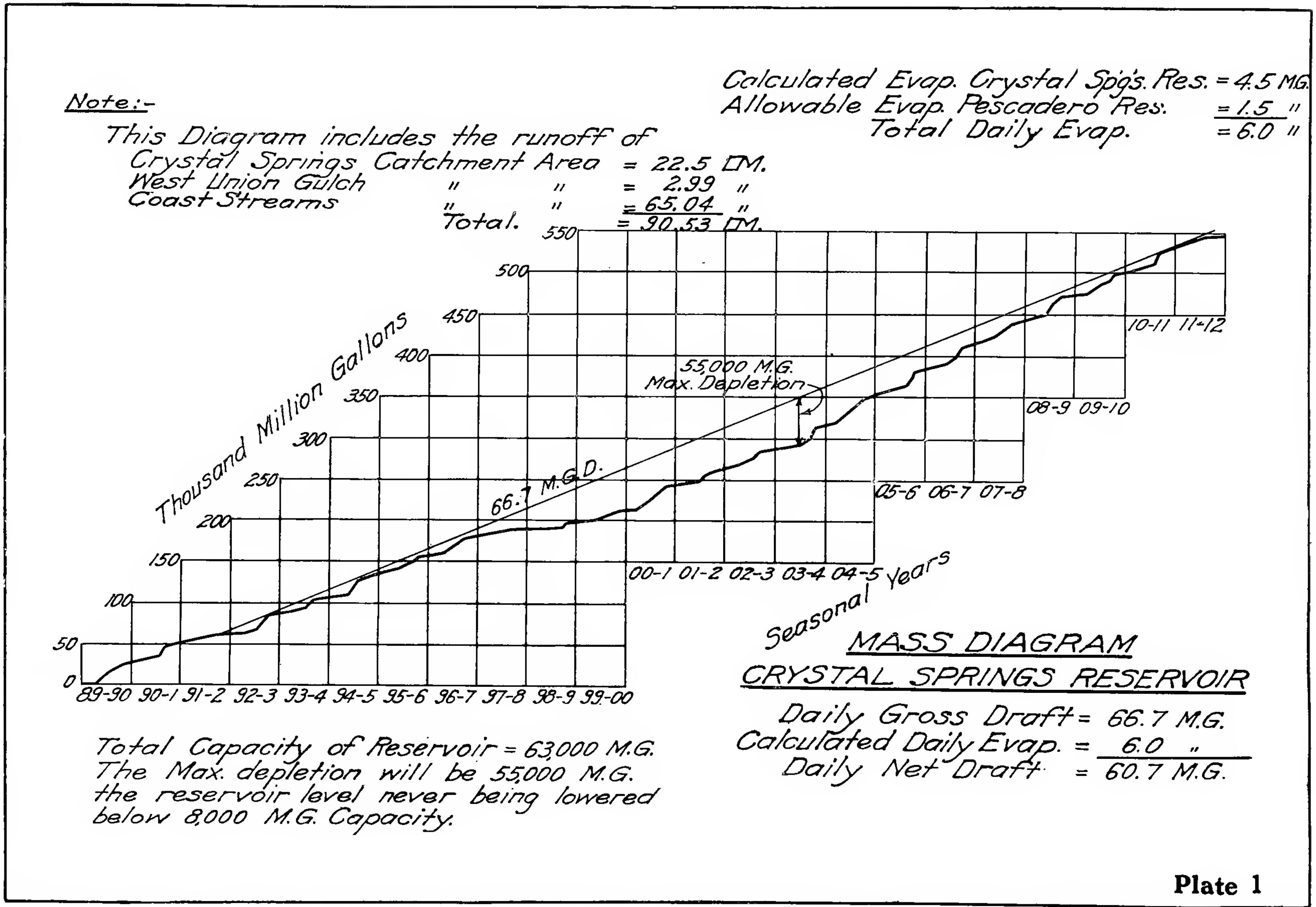


Plate 1

ADDING THE "COAST STREAMS" INSURES A YIELD OF OVER 60 MILLION GALLONS DAILY FROM CRYSTAL SPRINGS RESERVOIR ALWAYS LEAVING 8,000 MILLION GALLONS IN THE RESERVOIR FOR EMERGENCIES.

is limited by the thirty M. G. D. capacity of the 100 M. G. D. tunnel that is provided for pumped water, while for the remaining 305 days the rate of pumping may be as high as 50 M. G. D. In case of urgent necessity the spare unit may also be operated, the effort being to transfer the water as rapidly as possible to the Crystal Springs Reservoir, to leave the Pescadero Reservoir empty at the beginning of each rainy season.

The Coast Streams Will Yield over Fifty Million Gallons Daily with Pescadero Reservoir.

Plate G-3 shows a hydrograph for the past 23 seasons, upon which is indicated the total run-off from the catchment area above the gravity diversion. This run-off is divided into that portion which flows directly into Crystal Springs Reservoir limited to a rate of 70 M. G. D. and that portion which escapes to the Pescadero Reservoir.

Plate G-4 consists of a mass curve showing cumulatively all the waters which, under this plan, would have reached the Pescadero Reservoir for the last 23 years. On this mass diagram are also shown the rates of pumping required to transfer the water to the Crystal Springs Reservoir.

It is observed that pumping at the rate of 50 M. G. D. would be required in 1889-90 and in 1890-91. Between 1890-91 and 1903-04 pumping at rates up to about 46 M. G. D. would be required. The spare unit would be used in addition to the rated pumping capacity in the seasons 1904-05 and 1907-08, in each of which seasons the rate of pumping, except when limited to 30 M. G. D. in times of flood, would be sustained at 75 M. G. D. For all other seasons between 1903-04 and 1911-12 the maximum rate of pumping would be 50 M. G. D., the final result being that the Pescadero Reservoir would be empty to receive the floods of the season 1912-13.

By this combination the water yield of the Coast Streams above the Pescadero Reservoir from a catchment area of about 65 square miles would average 50.2 M. G. D. for the last 23 years.

West Union Creek Addition.

The upper part of the water shed of West Union Creek, including McGarvey Gulch, embraces an area of 3 square miles. The larger portion of this catchment area, including the place of diversion whence it is proposed to construct a tunnel about 2800 feet long to a point near the southerly end of Crystal Springs Reservoir, is now owned by the Spring Valley Water Company. A small regulating reservoir will be formed by means of a dam in West Union Creek, and practically all the flood waters from this area will be diverted into the Crystal Springs Reservoir.

This area is covered with a dense growth of redwoods and other water-loving trees. For the purposes of this report the same rate of run-off per square mile has been assumed that has been measured in the Crystal Springs Reservoir catchment area, though it is believed that this is much less than actually occurs. Figures based on the above show that this catchment area will produce an average run-off of 1.54 M. G. D. Floods running as high as 70 M. G. D. per square mile are anticipated, and the tunnel has been planned accordingly.

Plate G-5 shows the plan of the diversion dam and tunnel, their location being indicated on Plate G-1.

The run-off of this area, as computed in Appendix "G," has been added to the measured run-off of the Crystal Springs records.

Ultimate Dependable Yield of the Peninsula System Will Be 74 Million Gallons Daily.

The water yield from the Pilarcitos and San Andreas Reservoirs and Lake Merced will remain the same as at present. That of the Crystal Springs Reservoir will be increased by the addition of the Coast Streams and the West Union Projects.

The quantity of water which will reach the Crystal Springs Reservoir each season is obtained by adding the delivery of water from the Coast Streams, both by the gravity diversion and by pumping from the Pescadero Reservoir, and that from the West Union Creek to the measured catchment of the Crystal Springs Reservoir for the last 23 seasons, after correction for evaporation loss. These are shown cumulatively in the mass diagram Plate 1.

From this mass curve it is found that with a storage of 63,000 M. G. a gross draft of 66.7 M. G. D. may be made, leaving 8000 M. G. in the reservoir at its lowest stage. This will re-

quire a dam 200 feet high, or 50 feet higher than the present crest.

By deducting the loss for evaporation the net dependable yield of the Crystal Springs Reservoir becomes 60.7 M. G. D.

In deduction for evaporation, allowance has been made for a loss of 1½ M. G. D. from the surface of the Pescadero Reservoir which is at the rate of 40″ per year. While evaporation to this extent would take place, it would be more than compensated for by the gain due to precipitation directly on the surface of the reservoir. However, full deduction for evaporation has been made in order that the results of this report may be conservative.

The net dependable yield of the Peninsula system then becomes as follows:

Crystal Springs Reservoir	60.7	M. G. D.
San Andreas Reservoir and Pilarcitos Reservoir	10.0	"
Lake Merced	3.5	"
Total	74.2	"

Plate G-1 shows the proposed development of the Peninsula System, not including Lake Merced.

THE ALAMEDA SYSTEM.

By the "Alameda System" is meant the catchment area of the Alameda Creek and its tributaries above the Sunol Dam.

The main tributaries of Alameda Creek are Calaveras, Honda, Upper Alameda, San Antonio and Laguna Creeks, the two main branches of the latter being the Arroyo Mocho and the Arroyo del Valle.

The combined catchment area of these main tributaries, together with other smaller tributaries above the Sunol Dam, embraces 620.5 square miles, distributed over Alameda, Santa Clara and Contra Costa Counties. It reaches from Mt. Hamilton on the south to Mt. Diablo on the north, and is bounded on the east by the main divide of the Coast Range Mountains, and on the west by the top of the ridge lying west of Sinbad and Alameda Creeks. The catchment area is nearly all mountains, rough and precipitous, and in parts practically inaccessible. The elevation of the catchment area ranges from about 200 feet above sea level at Sunol Dam to about 4400 feet above sea level at Mt. Hamilton.

Where not too precipitous, the mountains are well covered with a growth of brush and trees. The forest covering is most dense in the westerly portion of the catchment area, the density of vegetation decreasing toward the easterly boundary. This great catchment area of 620.5 square miles is divided into two main geographical divisions:

(a) The southerly or Calaveras Basin, which extends southerly from Sunol for a distance of 31 miles to the neighborhood of Mt. Hamilton, containing 233.54 square miles, and

(b) The easterly or Laguna Basin, which extends easterly from Sunol to Livermore, and thence southerly 33 miles, also to the region of Mt. Hamilton, having a length of 42 miles and containing 387.2 square miles.

For the purpose of analysis the whole catchment area has been divided into the following subsidiary areas:

Subsidiary Catchment Area.	Sq. Miles.	Altitude.
Livermore Drainage	258.34	700 to 2,200 ft.
Sunol Drainage	49.08	200 to 2,000 ft.
San Antonio	38.70	500 to 3,800 ft.
Upper Alameda	35.32	900 to 3,800 ft.
Arroyo Valle	140.80	700 to 4,100 ft.
Calaveras	98.30	700 to 4,400 ft.

Within the Alameda catchment area are five locations which offer excellent opportunities for the conservation of water in very large amounts. Three of these—Calaveras, San Antonio and Arroyo Valle—are valleys of considerable size, with narrow dam sites at their lower ends; and two—Sunol and Livermore—are very deep and extensive gravel deposits. All these reservoirs will be utilized in the development herein proposed.

The three proposed surface storage reservoirs are within the mountains and are, in fact, completely surrounded for a long distance in all directions by lands aggregating 37,000 acres, the ownership of which rests in the Spring Valley Water Company. Plate No. A-2 shows the location of these various places of storage with relation to the Alameda catchment area, as well as the subsidiary catchment areas above enumerated.

Precipitation on the catchment area is largely in the form of rain, though in the higher reaches much of it is in the form of snow. The proportion of snow and rain, of course, varies greatly, according to the character of the season.

Watershed Protected Better Than That of Any Other Large City.

Of the 620.5 square miles total catchment area,

550.5 square miles are mountains, and 70 square miles are valleys. The ownership of over 30,000 acres of the catchment area is still vested in the United States Government and the remainder is held in very large tracts. Since the time of first settlement, the large holdings have constantly been increasing in size, while the small holdings have been decreasing in number.

Because these upper mountains are rough and rugged except for relatively very small and restricted areas, they are totally unfit for farming. For this reason the already large holdings will continue to increase in size and the small holdings to diminish in number.

This transformation in the number and the size of holdings has been accompanied by a corresponding decrease in the number of people living within the vast watersheds above the reservoirs. A careful canvass recently made shows not more than 0.6 persons per square mile.

Comparing the population within the catchment area of the surface storage reservoirs with that of other large cities, we have the following:

Place.	Catchment Area.	Area, Sq. Mi.	Pop., 1910 Census.	Population Sq. Mi.	Mi. of R. R. on Area.
New York	Croton	360.44	23,019	64.00	78.0
New York	Esophus	255.00	8,694	34.00	30.5
Boston	Wachusetts	118.90	5,282	45.00	35.5
Boston	Sudbery	75.20	22,211	294.00	27.5
Boston	Cochituate	18.73	4,877	260.00	14.1
Rochester	Hemlock Lake	43.00	1,401	33.00	7.0
Syracuse	Skaneateles Lake	73.00	2,795	38.00	0.0
San Francisco	Calaveras	133.80	144	1.08	0.0
San Francisco	San Antonio	36.70	20	0.54	0.0
San Francisco	Arroyo Valle	141.00	23	0.16	0.0

Attention is called to the very small population on the watersheds above the surface reservoirs of the Alameda System as compared with that of large Eastern cities of the United States.

Pure Subterranean Waters at Sunol and Pleasanton.

The waters taken from the underground reservoirs (Livermore Valley and Sunol Valley) filter naturally through gravel for a long distance before being withdrawn for consumption. It takes years for the water to travel from where it enters the gravel to where it is taken out, and when withdrawn it is as clear as crystal. Because this filtration continues through long periods of time the quality of the water will always be maintained in the highest state of purity. The matter of the purity of underground water was carefully and thoroughly studied by Messrs. Burr, Hering and Freeman in their investigations of the underground waters of Brooklyn as a part of the water supply of Greater New York, and I quote their findings (page 564), as follows:

> "In a sandy soil like that which exists on Long Island it seems probably that nearly all of the ground water found under natural conditions at a depth of more than about 10 feet is perfectly safe for drinking, provided that it does not receive any immediate sub-surface pollution, and provided that it is collected in such a way as not to be contaminated from above. Any tubular well on Long Island driven to a depth of more than 10 or 15 feet, and not located near a sub-surface source of pollution, will probably yield water safe for drinking, even though the well be located in a comparatively densely populated region."

Regarding the same underground waters in Brooklyn, N. Y., Mr. Freeman, in his "New York's Water Supply", on page 540, says:

> "It is therefore probable that a given barrelful of water poured into the ground at B, 3 miles from the wells, would be at least 4 years in reaching the wells, and that any pathogenic bacteria would have been nitrified and rendered harmless—killed by starvation and suffocation—before reaching the vicinity of the wells."

Up to the present time none of the large volume of flood waters have been impounded in surface storage reservoirs, all the water withdrawn from the Alameda System being taken from the gravel reservoirs either at Sunol or Pleasanton. These waters have been subjected to rigid bacteriological analysis by Dr. Geo. W. McCoy, M. D., Bacteriologist, under the direction of Dr. Rupert Blue, M. D., Medical Officer in Command, United States Public Health and Marine Hospital Service. In their report they make the following remarks:

"A. *Alameda County Supplies:* These supplies, the Pleasanton Wells and the Calaveras Creek, the latter being passed through the Sunol Filter Beds, partake of the nature of deep and filtered waters respectively, and consequently a much higher bacteriological standard is demanded for them than for the waters from the variour lakes. The results are as follows:

Specimens from	Bacteria p. c. c. grown at room temp.	Bacteria p. c. c. grown at 37° C.	Colon Bacilli in 10 c. c.
Pleasanton Wells Gallery	3	3	None.

"These supplies may be dismissed with the statement that, judged by these results, they are excellent waters."

Dr. D'Ancona Says Alameda Creek Waters Are Exceptionally Pure.

Further, as to the quality of the water of the Alameda System for domestic supply, I quote from Dr. D'Ancona who, while Chairman of the Health Committee of the Board of Supervisors of the City and County of San Francisco, made the following statement:

"For the sake of the record I want to say that the Board of Supervisors a year ago directed the Board of Health to have the City Chemist and City Bacteriologist examine the waters of the Alameda Creek System. They started to have the waters of the entire system examined, but that proved to be too burdensome, and it seems to me that the people of the City and the Spring Valley Water Works are entitled to the results of those examinations. *They showed that the waters of the Alameda Creek System are of exceptional purity. It is a question whether any city in the United States has a water source that is hygienically as good as the water from the Alameda Creek System.* I think the Spring Valley Water Works are entitled to that knowledge, and the people of San Francisco certainly ought to know that the water from the main source of the city supply is hygienically good and of *exceptional purity.*"

Regarding the value of bacteriological analysis of domestic water supply, Prof. Newton, the noted London authority, says:

"Bacteriology is the most direct and delicate test of the safety of water for drinking purposes."

Results of examinations as above noted confirm the opinions of Messrs. Burr, Hering and Freeman in their "Report of the Commission on Additional Water Supply for the City of New York," and that of Mr. Freeman in his "Report on New York's Water Supply," above quoted.

J. R. Freeman Says Underground Waters Are Better and Cheaper than Surface Waters.

From the foregoing it is plain that the quality of the water to be developed in the Alameda System is the best that can be secured for domestic purposes, and that the underground storage reservoirs are of great value as a component part of the Alameda System. Regarding the value of underground supplies, Mr. J. R. Freeman, in discussing the value of the underground supply on Long Island, on page 537 of his "Report on New York's Water Supply," says:

"I am inclined to *regard the underground water stored in the interstices of the saturated yellow gravel above the blue clay, as affording the very best of storage, ample in volume, removed from pollution, and in many ways cheaper and better than the storage to be obtained from surface ponds or reservoirs,* and would be led to seek somewhat different means of taking out the ground water than those heretofore employed. It, at present, appears to me to be preferable to tap the saturated upper gravel at a depth of, say, 40 or 50 feet, at such frequent intervals that the level of the water table would not be so much disturbed locally as by the present methods of driven wells and pumping stations a mile or so apart.

"In the past, the surface streams and surface storage have stood first in favor and the ground water taken as a last resort. *I believe this order of preference can be reversed with probable advantage in safety to health and in economy of construction and in the lessening of damage claims.*"

J. R. Freeman Says Yield of Underground Sources May be Determined With Certainty.

On pages 538 and 539 of the same report, as to the possibility of determining the safe yield from an underground source, Mr. Freeman says:

"The area of the subterranean watershed can be learned in advance with sufficient accuracy to permit reliable estimates of the safe yield of wells at a given locality.

"Water flows 'down hill' in percolating through porous gravel just as certainly as on the surface, and by determining the elevation of the ground water and plotting its

contours, much as Mr. Kirkwood determined it in some of his earlier studies on the Brooklyn supply, the direction of flow and the true limit of the watershed could be made known with certainty."

and on pages 541 and 542 of the same report he further says:

"With a well tapping the saturated gravel at 50 feet below the surface the water may be expected to have become sterile by the time it has reached the point of withdrawal even though polluted on the surface.

"Out of the mean annual rainfall of 43.3 inches assume, as before, that 24 inches, or 2 feet in depth, soaks down into the porous gravel. If the gravel contained 33 per cent. of voids, then this 2 feet of rain soaking into the ground in each year would, as it slowly moved downward, if drawn off from the bottom, occupy a vertical space of 6 feet, somewhat as indicated in Figure 105.

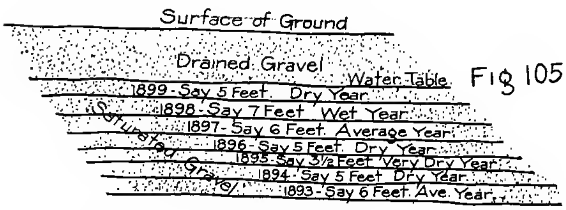


Fig 105

"If, therefore, we were certain that the gravel were equally pervious at all places—and it does appear to be nearly so—we would be fairly certain that rain water falling near the line of the wells and polluted by matters on or near the surface, would either be carried by and out to sea, if the draft by the well were a small portion of the whole, or if the wells were taking nearly the entire average yield, 5 or 6 years would elapse before it sank to the level of the well-point apertures through which it would be withdrawn; and in the meantime it would have become thoroughly treated by very slow sand filtration and any bacteria taken from the surface destroyed or starved.

"Considering in combination the principles stated in the two paragraphs above, and sketching the path of the rainfall on its way to the wells in Figure 106, it appears pretty nearly certain that any water reaching the wells either from near or distant points must have become thoroughly filtered on the way, and that *the health of the community will be much safer when using ground water properly collected* than when, as now, taking the main supply from surface drainage and from the surface outcrop of ground water and from open ponds in which algae or bacteria may thrive and into which a heavy shower may wash noxious matter from adjacent roads or fields."

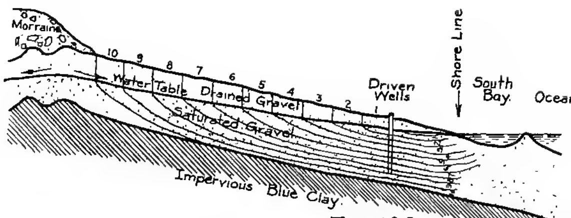


Fig. 106

As to the efficiency of an underground reservoir, Mr. J. R. Freeman, in discussing the Long Island underground supply in the same report, on page 546, says:

"This is, without doubt, one of the most remarkable, most extensive and most uniform gravel deposits in the world, and it would be difficult to imagine more ideal conditions for the gathering of a large and unfailing ground water supply. All requirements for the expense of storage reservoir is rendered unnecessary, for the interstices of the ground form a more capacious storage than is ever constructed by damming and flooding a valley and this subterranean reservoir is shielded from evaporation and from pollution, and will in all probability yield a larger safe yield per square mile of watershed than the highest line on Figure 49."

The Only Problem Is Amount of Water that Alameda System Will Yield.

The quality of the water being the best, the problem resolves itself into one of quantity. Stated in other words: When the Alameda System is completely developed, what will be the safe annual withdrawal that may be made from it?

This will be decided mainly by the following factors:

1. Precipitation—amount, distribution and occurrence.
2. Run-off.
3. Storage.
4. Other methods of conservation.
5. Losses: Evaporation and waste.
6. Efficiency of operation.

Over the first factor we have no control; the second may be modified to a slight degree by forestation; while the other factors, with the exception of evaporation, may be largely regulated by artificial measures.

To satisfactorily analyze the problem in hand, it is essential to segregate the run-off into that

which is tributary to the various storage reservoirs, both surface and underground, that it is proposed to utilize in developing and perfecting the Alameda Project.

Where sufficient detail run-off data are available, the problem is very much simplified, but where such data are incomplete an intimate knowledge of the catchment areas is essential, that the run-off data may be used in conjunction with those of the available rainfall. Measured run-off data are available for a long period in Alameda Creek below Sunol, and for shorter periods at other points within the watershed, the more important of which are at Calaveras and Arroyo Valle Reservoir sites.

Because of the fact that run-off data are not available over all of the catchment areas, indirect methods must be employed in order to determine the distribution of the run-off to the various catchment areas.

Good Judgment and Intimate Knowledge of Local Conditions Essential.

Judgment, based on intimate knowledge, both as to western conditions in general and as to local conditions within the Alameda watershed in particular, must be used in combining the rainfall and run-off data. Because of these ramifications the problem becomes involved and complex.

Several methods to distribute the total run-off from an entire catchment area into the proportional parts originating in its subsidiary catchment areas are common in engineering practice. All of these are dependent to a greater or less degree upon rainfall and judgment. Though in the last analysis the source of all run-off is rainfall, yet an absolutely rigid relation between the annual run-off and the annual rainfall does not exist.

This is due to the fact that run-off depends also upon other important factors, such as the occurrence and intensity of the rainfall. Thus, if a heavy rainfall is well distributed over several months, the resulting run-off will be less in quantity than if the same rainfall had occurred in a shorter time. The character of the watershed is also a large factor to be considered, as well as the position of the ground water within the catchment area. This latter factor cannot be expressed in figures. With a number of observations, however, average relations may be obtained, which, in lieu of actual measurements and when used with discretion, serve closely to approximate the distribution of run-off that is required for this study.

The Rainfall Must Be Studied Carefully.

It has been necessary to make a careful study of the rainfall in order to arrive at an accurate determination of the run-off in the Alameda System.

Climatic conditions along the Pacific Coast are much more favorable for an analysis of run-off based on rainfall, than is the case at other places in the United States.

The reason for this is that although there may be wide variation within the season between nearby rainfall stations, the seasonal rainfall at any one station is a very fair index of the rainfall at other stations in that vicinity.

Long records of rainfall are therefore of great value in expanding shorter records in the same general region. Advantage has been taken of this by many engineers in the development and solution of water problems on the Pacific Coast, and this method was lately used by Mr. C. E. Grunsky, then City Engineer, in his investigation of the resources of the water supply of San Francisco. Regarding the reliability of a single rainfall record in California as an index of rainfall in that region, Mr. Grunsky, on pages 497 and 498 of Vol. 61 of the "Transactions of the American Society of Civil Engineers," says:

> "Rain does not fall in California in every month of the year, as in the Eastern States. The rainy season begins in November and ends in April. So little rain falls from May 1st to the end of October that this period may be called rainless. There is no rain during this period which has any effect worthy of note upon the flow of streams.
>
> "Throughout the State, however, there is great variation in the normal annual rainfall, and, in the coast and central valleys, this is generally from 15 to 30 in. It rises to more than 70 in. in the Sierra Nevada Mountains, 150 miles northeasterly from San Francisco, and to more than 90 in. in the extreme northwesterly portions of the State; it is only 10 in. at some points of Sacramento Valley, and less than 6 in. in parts of San Joaquin Valley; it drops to only 2 to 3 in. in the Cahuilla (Salton) Basin. One feature, however, is especially noteworthy.

The rain storm is ordinarily an atmospheric disturbance of large extent. It is not of the same nature as eastern thunder storms, but is of the general type of winter storms which, in the East as in the West, sweep over vast areas. Owing to the wide distribution of rain in ordinary rain storms, and to the freedom from local storms, the rainfall records at single stations are better indices of the amount of precipitation on large tracts than is ordinarily the case for records of rain in the East and in the Middle West.

"With a view of illustrating the breadth of the storm area, it may be stated that the same atmospheric disturbances which brings rain to the Pacific Coast northerly from California, also brings rain to (or threatens with rain) all northern and central parts of California as far south as Tehachapi, where a mountain spur connects the Coast Range with the Sierra Nevada Mountains. As a rule, the greater the fall of rain at central points of this storm area the greater the surface extent of any cyclonic disturbance. The recurrence of rain storms (from six to twenty in a rainy season of 6 months) has the usual equalizing effect of repetition, and thereby increases the probability that the fall of rain in the course of a year, at any point of the central and northern portions of California, will bear a fairly uniform relation to the rainfall at some central point of observation, such as San Francisco or Sacramento. Exceptions to such a law are sure to occur, and have occurred. A notable exception was the rain distribution in 1867-68, in which an abnormally heavy fall of rain in the mountain region tributary to the San Joaquin Valley was not indicated by the rainfall conditions of that year at points in latitudes northerly from San Francisco."

Long Rainfall Record Is a Very Good Index of Precipitation Around San Francisco Bay.

This phenomenon has been used in utilizing many of the short and otherwise useless records within the watershed of Alameda Creek. This is particularly true of the large number of records in the neighborhood of Mt. Hamilton which are given by Messrs. Haehl & Toll, on pages 534 and 535 of Vol. 61 of the Transactions of the American Society of Civil Engineers. By comparison with longer records and by means of primary and secondary base stations all available rainfall records have been expanded to 63 years, and isohyetose lines have been constructed which, it is believed, represent very closely the normal annual rainfall at all points within this watershed. These are shown on Plate A-2. The normal annual rainfall varies between about 32 inches at Mt. Hamilton and about 14 inches near Altamont.

The mean area rainfall for the various catchment areas for the last 63 years has been determined to be as follows:

Name of Drainage Area.	Area in Sq. Miles.	Mean Area Rainfall for 63-Year Period in Inches.
Calaveras Creek	98.30	28.55
Alameda	35.32	27.75
San Antonio	38.70	23.93
Arroyo Valle	140.80	20.80
Drainage of Sunol Gravels	49.08	23.00
Livermore Gravels Drainage, including Arroyo Mocho and floor of Valley	258.34	18.55
Total area	620.54	21.84

In Appendix "A" is given the detailed study of the rainfall determinations and the methods by which the mean area rainfalls for each catchment area for each of the last 63 years were obtained.

Appendix "A" has been prepared by Mr. J. J. Sharon, Assistant Engineer, in the Engineering Corps of the Spring Valley Water Company. Mr. Sharon is equipped with a very intimate knowledge of the hydrology of this region by reason of the fact that for many years he was assistant to Mr. Hermann Schussler.

Measurements of Stream Flow Have Been Made.

The run-off of the whole Alameda System has been measured at Niles and Sunol Dams for the last 23 years, and shows an average daily flow of 145.00 M. G. D. for that period.

At Calaveras the run-off has been measured for the seasons of 1898-99 to 1907-08 and 1910-11 to 1911-12, and shows an average daily flow per year ranging from 25.21 M. G. D. to 81.83 M. G. D.

At Arroyo Valle the run-off has been measured for the seasons of 1904-05 to 1907-08, and shows an average daily flow per year ranging from 9.25 M. G. D. to 87.03 M. G. D. Measurements covering less than one season have been made on the Laguna, Arroyo Mocho, the Positas and San Antonio Creeks.

Comparing the actual measured run-off at Sunol with that at Calaveras and Arroyo Valle

for the periods covered by the two latter we have the following:

Seasons	Years	Sunol 620.5 sq. mi. M.G.D.	Cal. 98.3 sq. mi. M.G.D.	Arroyo Valle 140.8 sq. mi. M.G.D.
1898-9 to 1907-8	10	109.7	50.7	
1898-9 to 1907-8 and 1910-12	12	115	50.4	
1904-5 to 1907-8	4	146	60.4	38.5
1904-5 to 1907-8 and 1910-12	5	122.7	51.5	31.4

NOTE: Prior to 1900 the Alameda Creek was measured at Niles Dam, the tributary catchment area being 631.0 square miles; since 1900 it was measured at Sunol Dam, the tributary catchment area being 620.5 square miles.

Alameda Creek Measurements Covering Period of 23 Years Are Conservative.

Measurements have been taken of the run-off of Alameda Creek for the last 23 years, as previously stated, the measurements being taken at Niles Dam prior to 1900 and at Sunol Dam since 1900.

Daily gage heights were kept at the Niles Dam from 1889 to 1900. In 1900 the Sunol Dam became the place of measurement of the Alameda Creek, and gage heights were taken daily during low water flow and at more frequent intervals during flood, the frequency depending upon the fluctuations in water depth over the dam. Discharge was computed by the ordinary weir formula, no allowance being made for the great increase of flow due to velocity of approach nor to decrease due to submergence. Recently these discharges have been recomputed from the original data by a commission composed of Mr. C. E. Grunsky, Consulting Engineer; Prof. C. D. Marx, Professor of Civil Engineering at Stanford University, and Prof. Charles Gilman Hyde, Professor of Sanitary Engineering at the University of California. These gentlemen were appointed by the City of San Francisco, at the request of Mr. J. R. Freeman.

In examining the original records this commission found that in previous computations over a considerable period of the years 1901 to 1903, gage rod readings 4½″ to 6″ less than the actual were used by the Spring Valley Water Company, so that regardless of what formula or method be used in the computations of flow, the discharge over Sunol Dam would be very materially increased for these years. They kindly called my attention to these errors.

Professor Le Conte Makes Scientific Analysis.

At about the same time that these gentlemen were engaged in these recomputations, I requested Prof. J. N. Le Conte, the eminent hydraulic specialist of the University of California, to make an independent determination of the discharge curves to be used in computing the flow over Niles and Sunol Dams. After very careful consideration, he elected to make a series of experiments with models 1/20 of the actual size of these structures. He went into the question of submergence and of velocity of approach in detail, and by means of recognized hydrodynamic laws constructed a discharge curve for each of these dams which I believe is more reliable than any theoretic deductions unsupported by experiment on these exact types of dams.

Computation of discharge from channel measurements check the results found by Prof. Le Conte for high water stages.

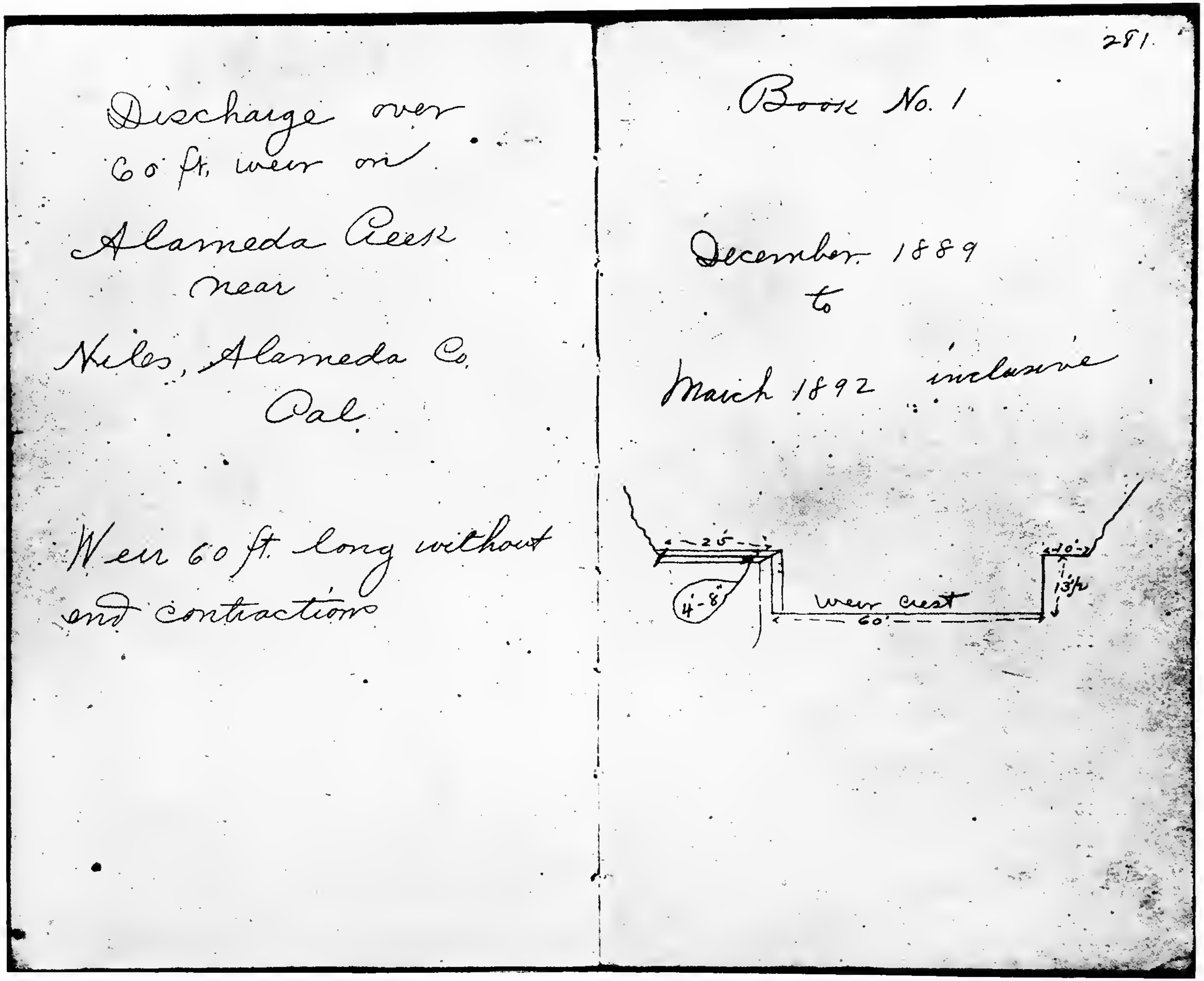
Prof. Le Conte's report on his experiments was made available to Messrs. Grunsky, Hyde and Marx, and it is to be regretted that the results of the work of these gentlemen were suppressed. Prof. Le Conte's report, together with independent channel and weir computations for the highest stage of water in the flood of March, 1911, made by Mr. T. W. Espy, are given in Appendix "C."

From Prof. Le Conte's curves and the original data, I have recomputed the discharge of Alameda Creek for the 23 years ending July 1, 1912. These are given in detail in Appendix "B" on "run-off," prepared by Mr. J. J. Sharon, a summary of same being as follows:

ALAMEDA CREEK DISCHARGE—1889-90 to 1911-12.

(Million Gallons.)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Total.
1889-90	.....	.....	.....	.....	....	36310.8	68865.7	32833.3	18987.0	4873.0	2886.0	1151.2	165907.0
1890-91	824.6	740.0	665.4	696.8	695.1	1247.4	1340.5	12913.2	14462.5	3049.1	1394.2	902.3	38931.1
1891-92	530.6	255.3	200.8	205.2	198.2	3341.8	1752.0	1779.9	5691.2	3768.3	2422.9	758.9	20905.1
1892-93	618.2	181.8	126.5	126.1	14498.7	39676.2	13657.0	22017.2	18104.5	5457.6	2415.0	632.1	117510.9
1893-94	638.5	513.1	383.9	263.0	353.9	640.8	16221.0	33310.1	4300.6	1187.6	810.6	579.1	59202.2
1894-95	422.9	237.3	171.2	349.8	200.6	17529.2	46689.8	12714.4	3483.5	2194.2	1792.5	636.5	86421.9
1895-96	397.5	324.2	320.6	439.4	477.9	545.7	19407.3	2195.0	2377.0	9995.8	2736.0	750.1	39966.5
1896-97	454.6	320.2	315.4	343.7	1663.9	2611.8	2639.7	25507.6	27288.0	4708.5	1354.0	564.0	67771.4
1897-98	318.7	285.9	225.8	254.8	208.8	151.5	264.2	972.5	842.7	431.5	307.2	234.3	4497.9
1898-99	179.7	146.6	146.6	226.9	231.4	226.9	643.2	273.8	18925.7	1262.3	502.4	325.6	23091.1
1899-00	263.8	231.7	216.8	242.3	657.3	2296.3	9999.1	864.2	2412.6	944.5	653.2	303.5	19085.3
1900-01	250.0	233.1	222.4	423.9	7695.3	1302.6	3847.2	18780.1	3413.4	1590.1	1494.9	785.3	40038.3
1901-02	542.9	394.5	288.4	288.5	297.4	717.2	514.5	9902.0	13419.9	2636.8	1240.1	619.2	30861.4
1902-03	394.2	346.2	271.4	299.4	406.6	380.2	4420.4	6020.2	12723.4	10657.8	1339.4	594.8	37854.0
1903-04	559.1	443.5	356.6	332.8	896.7	509.3	626.8	8513.0	15878.0	5354.9	2291.8	701.1	36463.6
1904-05	544.7	473.3	356.1	364.3	377.5	601.6	1541.7	4017.0	6963.7	2435.9	2091.9	683.1	20450.8
1905-06	510.8	451.9	319.8	283.3	268.6	286.5	17552.5	7994.4	27080.3	8680.0	2617.4	1621.9	67667.4
1906-07	675.5	523.2	501.5	460.3	424.2	6303.9	22146.3	8716.2	53788.4	7268.5	2632.4	1415.9	104856.3
1907-08	1170.0	789.2	547.7	547.3	677.5	1372.2	4846.9	4668.8	3619.0	1091.9	838.0	534.6	20703.1
1908-09	529.6	407.1	437.8	309.2	292.7	336.5	35315.0	31498.7	6847.8	1995.4	859.5	641.1	79470.4
1909-10	575.6	506.2	483.2	535.8	476.4	3308.6	11465.9	4526.5	5671.9	2652.3	1183.7	638.6	32024.7
1910-11	539.4	518.9	410.7	226.7	294.7	443.3	28796.7	14890.6	41950.9	2471.9	1207.3	674.2	92425.3
1911-12	617.4	620.6	507.3	557.4	555.0	612.0	1210.1	1057.5	2928.5	1103.9	642.8	524.9	10937.4
Total.	11558.3	8943.8	7475.9	7776.9	31848.4	120752.3	313763.5	265966.2	311160.5	85811.8	35713.2	16272.3	1217043.1
M. G. D.													145.0



Discharge over
60 ft. weir on
Alameda Creek
near
Niles, Alameda Co.
Cal.

Weir 60 ft. long without
end contractions

281.

Book No. 1

December 1889
to
March 1892 inclusive

Plate 2

THE SKETCH SHOWS THE WATER AREA OF THE NILES DAM USED BY THE UNITED STATES GEOLOGICAL SURVEY TO COMPUTE THE FLOW OF ALAMEDA CREEK, AS PUBLISHED IN WATER SUPPLY PAPER NO. 81.

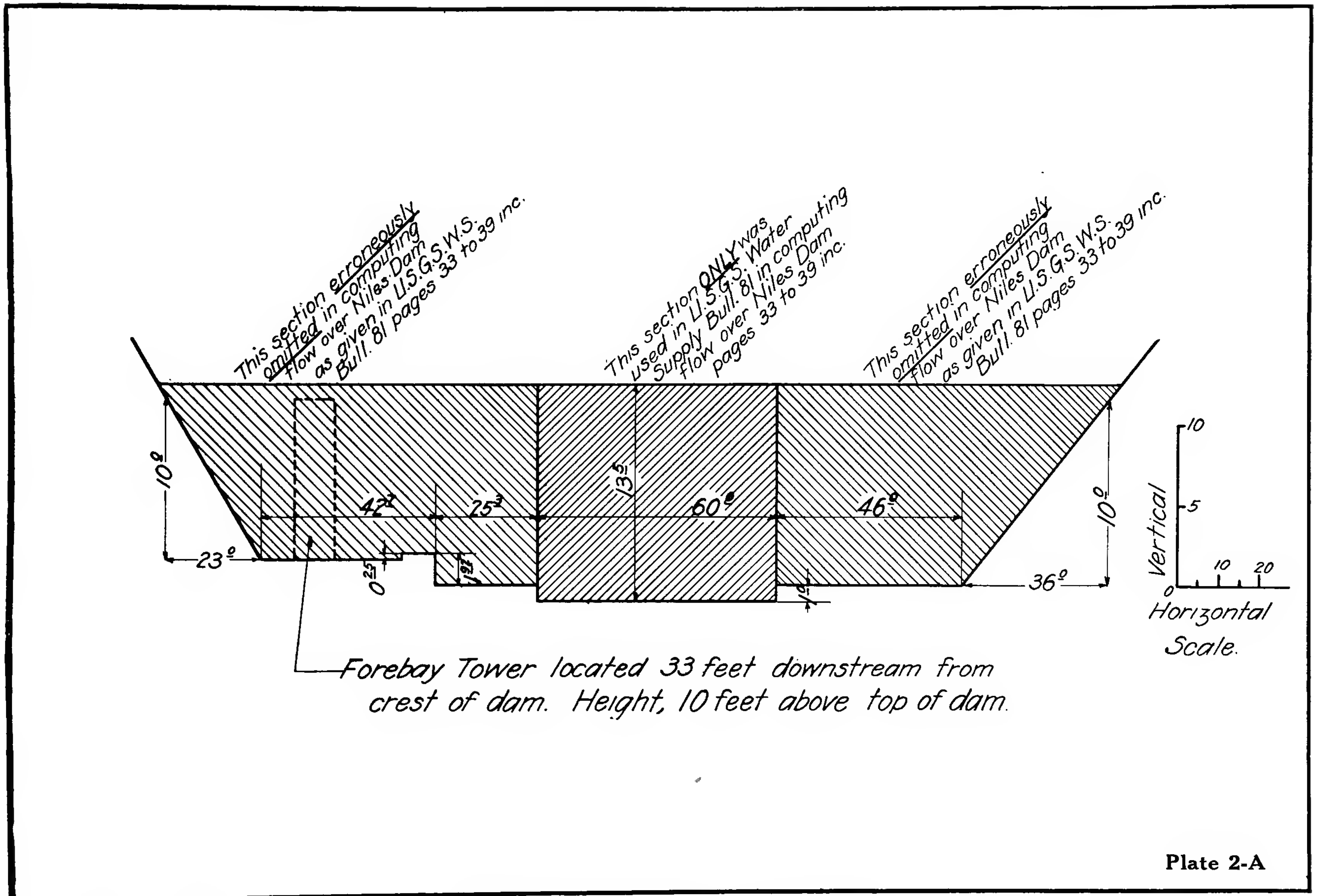
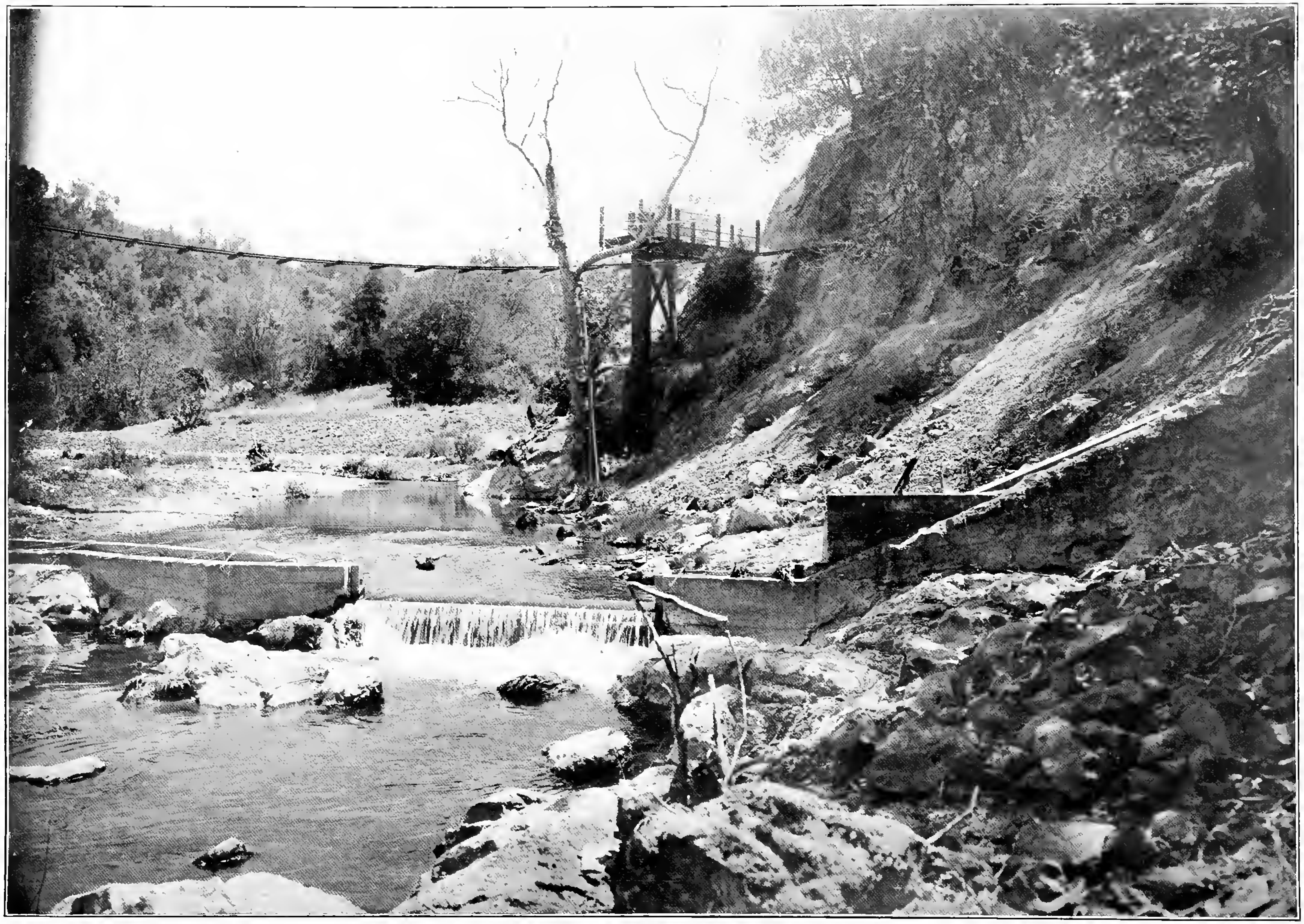


Plate 2-A

WATER CROSS SECTION AT NILES DAM.

Note that during periods of flood the U. S. G. S. used less than half the section (Water Supply Paper 81).



MEASURING STATION CALAVERAS CREEK.
The Concrete Weir is Used for Low Flows. High Flows are Measured from Suspension Bridge with a Current Meter.

Results in Bulletin No. 81 Are Too Low.

A partial estimate of the flow of the Alameda Creek over Niles Dam from 1889 to 1900 is given in Water Supply Paper No. 81, of the U. S. Geological Survey, which is a compilation of a great many water measurements in California prior to 1902. Accuracy in the results published therein is particularly disclaimed by the author.

The estimates of flow in Alameda Creek, given in this bulletin, were obtained from a series of daily gage heights indicating the depth of water over the Niles Dam as given in a certain Exhibit No. 11, in the case of "Clough vs. the Spring Valley Water Company", in the Superior Court of Alameda County, no discharges whatever being given in this or any other exhibit in this case.

Taken over the period covered, the estimates given in Water Supply Paper No. 81 give results about 32% less than those used by the Spring Valley Water Company prior to the Le Conte experiments, and about 37% less than those determined from the Le Conte experiments.

It is a striking fact that in periods of low water flow the estimates in Bulletin No. 81 are in excess of those of the Spring Valley Water Company, while in flood periods they are very much smaller.

Realizing that, by reason of the fact that no allowance had been made for the great effect of high velocities of approach in the unrevised discharge tables of the Spring Valley Water Company, the quantities contained therein should properly be increased instead of diminished, search was made for the books of the U. S. Geological Survey which contained the computations of the discharge over Niles Dam given in Bulletin 81. Mr. Lippincott, who had gathered the data from which the results in this bulletin were compiled, found the computations in four books in the Los Angeles Office of the U. S. Geological Surveys. (Nos. 281, 282, 283 and 284.)

An Amazing Mistake.

The sketch on the front page of book No. 281 shows that a weir crest 60 feet long was used throughout in making the computations, the depth of the 60-foot notch in the Niles weir being considered as *13 1-2 feet high* instead of *12 inches* as is the actual condition. Plate 2 is a photostat of the front page of book No. 281.

Thus it is seen that when the depth of water was over 12 inches, less than one-half the proper cross-sectional area of the stream was used, which obviously gave results that in some cases were less than 50 per cent of the proper amount. On Plate 2-A (page 19) is shown the cross-sectional area used in bulletin No. 81 together with that which was omitted, but which should have been used in addition to what was used.

Floods Were not Included.

In some places where Exhibit No. 11 indicated a crest length of 120 feet, the man who computed the discharges in Bulletin No. 81 was evidently at a loss to know what to do. The result was that he omitted entirely the discharge on these dates. Obviously this increased the error in this work.

Numerous trials reveal the fact that in computing the discharge, summation of which is given in Bulletin No. 81, the ordinary Francis weir formula was used, no allowance being made for either the increase due to velocity of approach or the decrease due to submergence.

It is therefore seen that the partial records of the discharge of Alameda Creek, as given in Water Supply Paper No. 81, are of no value whatsoever.

Calaveras Has Record of Twelve Years' Stream Flow.

Run-off measurements at Calaveras Creek are available for the periods 1898-9 to 1907-8 and 1910-11 to 1911-12. Discharges from the original measurements have been recomputed, the details being given in Appendix "B".

Records of computation for the period 1898-1903 are not available, though computations of the period 1903-4 to 1907-8, made under the direction of Mr. Cyril Williams, Jr., are available.

The computations of the period 1898-9 to 1902-3, as given in this report, have been made by Mr. Sharon under my direction, while the recomputation of the so-called Williams measurements has been made under the direction of Mr. G. G. Anderson, Consulting Engineer, who has had vast experience in hydraulic problems in Colorado and contiguous states, as well as on

the large hydraulic developments in various parts of British Columbia.

The results of the recomputations for the period 1903-8 differ considerably from the previous computation made under the direction of Mr. Cyril Williams, Jr., and used heretofore by the Spring Valley Water Company.

Following is a record of new computations and a comparison of the results with those made under the direction of Mr. Williams.

CALAVERAS GAGINGS.

Season.	Anderson's computation.	Williams' computation.
1903-04	19,380 M. G.	16,485 M. G.
1904-05	14,902 "	16,503 "
1905-06	26,962 "	32,551 "
1906-07	37,146 "	54,407 "
1907-08	9,203 "	14,147 "

Arroyo Valle Has Five Years' Stream Flow Record.

Run-off measurements at Arroyo Valle are available for 1904-5 to 1907-8 and a part of 1911-12.

We have been unable to find the original records in the files of the Spring Valley Water Company, and Mr. Cyril Williams, previously in the employ of the Spring Valley Water Company, states that the earlier ones were outside of the vault in the fire of 1906 and were consequently destroyed. Fortunately, however, I obtained a copy of the records from Mr. F. Gainor, who was watchman at the Arroyo Valle at that time and made a copy of the records he took. This copy was used in computing the discharge of Arroyo Valle for the period 1904-5 to 1907-8. The measurements for a part of 1911-12 were made by current meters and weirs. The results of these computations are as follows:

ARROYO VALLE RUN-OFF

From F. Gainor's Gagings—In Seasons.

	1904-5 M. G.	1905-6 M. G.	1906-7 M. G.	1907-8 M. G.
July	*30	*30	*30	*30
Aug.	*30	*30	*30	*30
Sept.	*30	*30	*30	*30
Oct.	*50	*30	*30	*30
Nov.	*60	*30	*30	*30
Dec.	*200	*50	1,495	294
Jan.	*500	6,234	10,618	1,613
Feb.	589	788	1,195	1,095
Mar.	2,290	7,967	18,125	*100
Apr.	222	1,457	*100	*60
May	185.70	199	*80	*30
June	*60	36	*30	*30
Totals	4,246.70	16,881	31,793	3,372

NOTE: *—Indicates estimated quantity.

The Niles-Sunol record of Alameda Creek is the only one that is long enough to give representative results, as it covers cycles of wet and dry years.

From these records with the aid of run-off data available for the subsidiary catchment areas and the corresponding rainfall records, a run-off curve has been plotted for each subsidiary catchment area. These run-off curves represent average results for various rainfalls and are used for the period 1849-50 to 1889-90 by applying to them their respective mean area rainfall. They are shown on Plates Nos. B-1 to B-4, inclusive, Appendix "B".

It is realized that a single run-off curve for a catchment area will give only average results, and that any single determination from such a curve may be either considerably less or considerably more than the actual run-off. Such curves serve their purpose very well where, as in this case, they are used to ascertain whether the record in hand, covers all conditions of wet and dry year cycles that may be encountered. In this case, we have a 23-year record at Sunol with an expanded rainfall record of 63 years. Application of these run-off curves to the rainfall records reveals no cycles nor even single years more severe than are found in the 23-year measured run-off record. To show this clearly the run-off prior to the 23-year record is shown in conjunction with that of the 23-year record on the mass curves for each of the various subsidiary catchment areas. (See Plates B-2, B-3, B-6, B-7, B-10 and B-11, Appendix "B".)

Closer Results Obtained by Grouping Years on Series of Curves.

Because of the fact that a single run-off curve gives but average results, and in order that for the 23-year period we may obtain more closely the run-off for the same rainfall under various conditions that are reflected in the measured run-off records of this period, where we have a number of actual gagings representing the run-off from the subsidiary catchment areas within the Alameda watershed, a set of five run-off curves has been made for each subsidiary drainage area. The purpose of this is to group the seasons according to run-off conditions. Thus the seasons in which for one reason or another the run-off

is a high percentage of the precipitation are represented on a curve which gives results somewhat higher than does the curve for the years where the conditions were not so favorable for high run-off. Likewise that group of years which for one reason or another yielded very small run-offs for the rainfall is represented by another line which fits their conditions. (See Plates B-5, B-6 and B-7, Appendix B.)

By use of these curves we are enabled to determine very closely the annual run-off from the various subsidiary catchment areas for each year, as the curves thus constructed are based upon run-off conditions reflected by the measured run-off from either the entire Alameda catchment area or one of the subsidiary catchment areas.

Detailed discussion of the construction of these run-off curves is given in Appendix "B".

The Gross Run-off of Alameda System Averages 173 Million Gallons Daily.

The final results of the run-off of the various subsidiary catchment areas for the 23-year period, details of which are given in Appendix "B", are as follows:

The summation of the run-off from each of the subsidiary catchment areas shows an average gross water crop of 173.39 M. G. D. from 620.5 square miles, equal to an average of about 275,000 gallons per square mile per day. This is two-thirds the average rate of run-off from the Crystal Springs catchment area, and about one-fourth that of the Pilarcitos catchment area.

The difference between this gross water crop of 173.39 M. G. D. and the average measured run-off over Sunol and Niles Dams of 145.00 M. G. D. represents the average loss in transit, including the evaporation from saturated soils in the western portion of Livermore Valley.

From the foregoing measured run-off data, we note that the Alameda Creek furnished a bountiful supply of water. Taking the records of these 23 years, it averages 145.00 M. G. D., equivalent to approximately four times the present needs of the City of San Francisco, Sufficient to serve the City of San Francisco until about the end of the present century.

Destruction and Suffering Due to Alameda Creek Floods.

Single floods running as high as 17,830 M. G. D., or equivalent to 48.9 M. G. D. for a whole

RUN-OFF FOR SUBSIDIARY CATCHMENT AREAS FOR 23-YEAR PERIOD 1889-1912.

Season	Calaveras 98.30 sq. mi. M. G. D.	Upper Alameda 35.32 sq. mi. M. G. D.	San Antonio 38.70 sq. mi. M. G. D.	Arroyo Valle 140.80 sq. mi. M. G.D.	Sunol Drainage 49.08 sq. mi. M.G. D.	Livermore Drainage 258.34 sq. mi. M. G. D.	620.54 sq. mi. Total M. G.D.
1889-90	126.50	43.73	38.25	100.54	48.50	129.20	486.70
1890-91	43.60	11.40	5.99	31.85	7.94	27.81	128.40
1891-92	39.8	11.8	5.99	13.41	6.43	13.55	90.97
1892-93	100.7	32.6	22.50	88.50	23.95	56.44	324.86
1893-94	73.6	21.0	13.37	38.55	12.85	27.72	187.10
1894-95	82.	29.4	19.36	52.30	20.45	52.33	255.80
1895-96	50.4	14.3	7.83	26.83	8.76	27.72	135.80
1896-97	69.10	22.88	14.29	43.56	15.19	55.34	220.30
1897-98	8.9	2.0	.55	2.01	1.12	.....	14.65
1898-99	37.6	9.9	7.37	11.40	8.18	12.31	86.77
1899-00	39.9	10.1	6.92	6.70	6.54	9.24	79.37
1900-01	56.3	18.1	13.83	23.47	18.23	17.24	147.10
1901-02	36.7	9.67	6.92	22.13	7.01	15.39	97.82
1902-03	42.4	11.3	7.01	32.18	7.60	30.78	131.30
1903-04	53.1	14.3	8.85	23.46	12.15	24.63	136.50
1904-05	40.8	13.6	10.14	11.63	9.82	18.47	104.50
1905-06	73.8	16.8	13.79	46.25	18.23	61.57	230.50
1906-07	101.8	26.2	22.49	87.02	29.23	119.50	386.20
1907-08	25.2	5.9	4.61	9.25	5.26	12.31	62.53
1908-09	82.0	23.9	16.13	46.93	21.04	55.37	245.30
1909-10	35.6	9.25	7.84	20.11	8.18	23.40	104.30
1910-11	81.4	25.65	23.05	65.71	34.35	70.20	300.30
1911-12	15.2	3.78	3.69	2.66	5.37	0	30.72
Average M. G. D.	57.23	16.86	12.21	35.06	14.62	37.41	173.39

year, have passed down the Niles Canyon, creating havoc on the way and finally destroying the crops on many square miles of farms between Niles and the San Francisco Bay, besides endangering the lives of residents in its path. Bridges, roads and railroads are washed out, the roads being made impassable for weeks and even months at a time.

These large fluctuations within the season are typical of all western streams to a greater or less degree. Aside from the fluctuations within the season, the annual stream flow of western streams is subject to fluctuations covering longer periods of time due to pronounced cycles of wet and dry years. This is common knowledge among hydraulic engineers conversant with western conditions, making long period run-off data such as those of the Alameda Creek exceptionally valuable. Concerning this characteristic, Mr. C. E. Grunsky, on pages 498 and 505 of Volume 61 of the Transactions of the American Society of Civil Engineers, says:

Grunsky Says Storage Similar to Spring Valley Works Necessary in the West.

"One of the early observations made by the engineers who from time to time have been consulted on the subject of an adequate water supply for San Francisco was the recurrence in succession of so-called dry winters, that is, of rain years with a fall of rain so far below normal as to be classed as minimum years. Two such years now and then follow each other, and there may be a series of year, up to about ten, of which none materially exceeds the normal. As the years of minimum rainfall produce practically no run-off from areas near San Francisco, and years of normal rainfall only a moderate amount, the conclusion was reached that the storage capacity when compared with the run-off from the area tributary to a reservoir should be relatively large, and that the aggregate storage capacity should be equivalent to about 900 days' supply.

"It remains to be stated that all three of these reservoirs are of relatively large capacity when compared with the small tributary areas. There are, therefore, many seasons in which there is no waste, in which all water is caught. This is particularly true of Crystal Springs Reservoir, which has been full only twice. There is, moreover, a certain interdependence between the reservoirs. The relation in which the Pilarcitos Reservoir stands to the San Andreas Reservoir is so close, in fact, that it has seemed advisable to combine the two and treat them as a single reservoir in this discussion. The arrangement is such that the waste from the Pilarcitos flows to the San Andreas until the conduit capacity is exceeded, whereupon some water goes to the stream. Any excess of water received by the San Andreas Reservoir is in turn delivered to the Crystal Springs Reservoir."

Alameda Creek Record Excellent, Because It Includes Cycle of Extremely Dry Years.

It is observed that the record of the run-off of Alameda Creek below Sunol includes cycles of this character, which may be brought out by dividing it into three periods of about eight years each.

ALAMEDA CREEK RUN-OFF FOR 23 YEARS FROM ACTUAL GAGINGS.

Seasons	Length of Period.	Annual Flow in Million Gallons Average	Max.	Min.
1889-90 to 1896-97	8 yrs.	25,940	165,907	20,905
1897-98 to 1904-05	8 yrs.	9,233	40,038	4,498
1905-06 to 1911-12	7 yrs.	17,580	104,856	10,937

Fortunately the record of Alameda Creek includes the extremely dry cycle of eight years from the season of 1897-8 to the season of 1904-5. As previously stated, this cycle exceeds all others indicated by the 63-year rainfall record, both as to duration and lack of moisture. The testimony of old men living at the time of this extremely dry period establishes it as the most excessive within the memory of man on the Pacific Coast. Other very dry years have occurred singly or in pairs, or distributed between very wet years and moderately dry years in groups of three. This eight-year dry period prevailed all over the Pacific Coast.

The cycle of dry seasons is in the middle third of the Alameda record, therefore we may be sure that calculations based upon data in which it is included will be well within the limits of safety.

Long cycles of this sort are not to be found along the Atlantic Coast. One of the longest and dryest of which we have record covers the three years just passed, and created great uneasiness among hydraulic engineers in eastern practice.

Storage Is Common Sense Method of Meeting Cycle of Dry Years.

Series of wet and dry years are typical of western climatic conditions and are anticipated by western hydraulic engineers just as the business man and the farmer anticipate series of years in which good and bad crops will be harvested. The common sense method of storing enough in the years of plenty to tide over the time of drought is equally applicable in both cases. This is what we propose to do in the Alameda system, so that storage of water becomes a cardinal factor in its development as in other western projects.

What Storage Did for San Francisco.

Because of its extensive stored water supply on the San Francisco peninsula the people of San Francisco had ample water during the cycle of eight dry years above noted, and at the end of this period there still remained sufficient stored water to supply the City for 500 days longer. During this period the stored water was drawn upon constantly, the water surface of the reservoirs being gradually lowered. For an interval of nine years the water surface of the Crystal Springs Reservoir was continuously below its flow line. This practice is not looked upon with favor in some parts of the humid Atlantic Coast, where effort is made to limit the interval of time to two or three years.

What Some Engineers Do in the East.

This view and the reason therefor are expressed in the report of Messrs. Burr, Hering and Freeman on the New York Water Supply, page 23, where they say:

> "It is essential not to overestimate the yield of a given territory in which reservoirs are to be constructed, for the reason that the daily draft of the distribution system will at times deplete the storage and expose a margin around the perimeter of the reservoir. If this uncovered margin is exposed through too long a period, vegetation will spring up on it and prejudice the quality of the water when the reservoir is again filled."

More Eastern Practice.

In New England, in the effort to produce wholesome water, the soil within the reservoir has been stripped to such a depth as to remove all organic growth. This heroic treatment has proved futile and expensive and has been repudiated by the builders of the reservoirs for the water supply of Greater New York now under construction.

What They Do in the West.

The exposed margins of the Crystal Springs reservoir were kept scrupulously free from weeds, etc., by the Spring Valley Water Company during the successive years its water surface was below the flow line. Contrary to the contention that the water would deteriorate in quality because of this practice, the quality of the Crystal Springs reservoir water remained uniformly good.

It may be that the care taken with regard to the margin of the Crystal Springs reservoir, together with the climatic conditions which prevail here, account for the different results obtained in the East and in the West in this matter. However this may be, Western experience and particularly the experience of San Francisco itself, leads to the only reasonable conclusion that it is not alone harmless to maintain a reservoir water surface below the flow line for a long number of years, but that it would be wasteful and the height of imprudence not to take advantage of the climatic and the physical conditions with which we are favored.

Western Practice Applied by Eastern Engineers.

Due regard was taken of this difference between eastern and western conditions by the Board of Consulting Engineers (Messrs. Freeman, Stearns and Schuyler), who approved the plans of the Los Angeles Aqueduct, that great work to bring the waters of the Owens Valley to Los Angeles which was conceived, designed and built by Mr. Wm. Mulholland, and which is now practically completed. This Board of Engineers includes in the final project the Long Valley Reservoir, the office of which is *"to provide against a series of dry years"*, by maintaining a continuous, uniform flow equal to the capacity of the aqueduct under conditions of full development. In the study of the Long Valley Reservoir, discharge from the

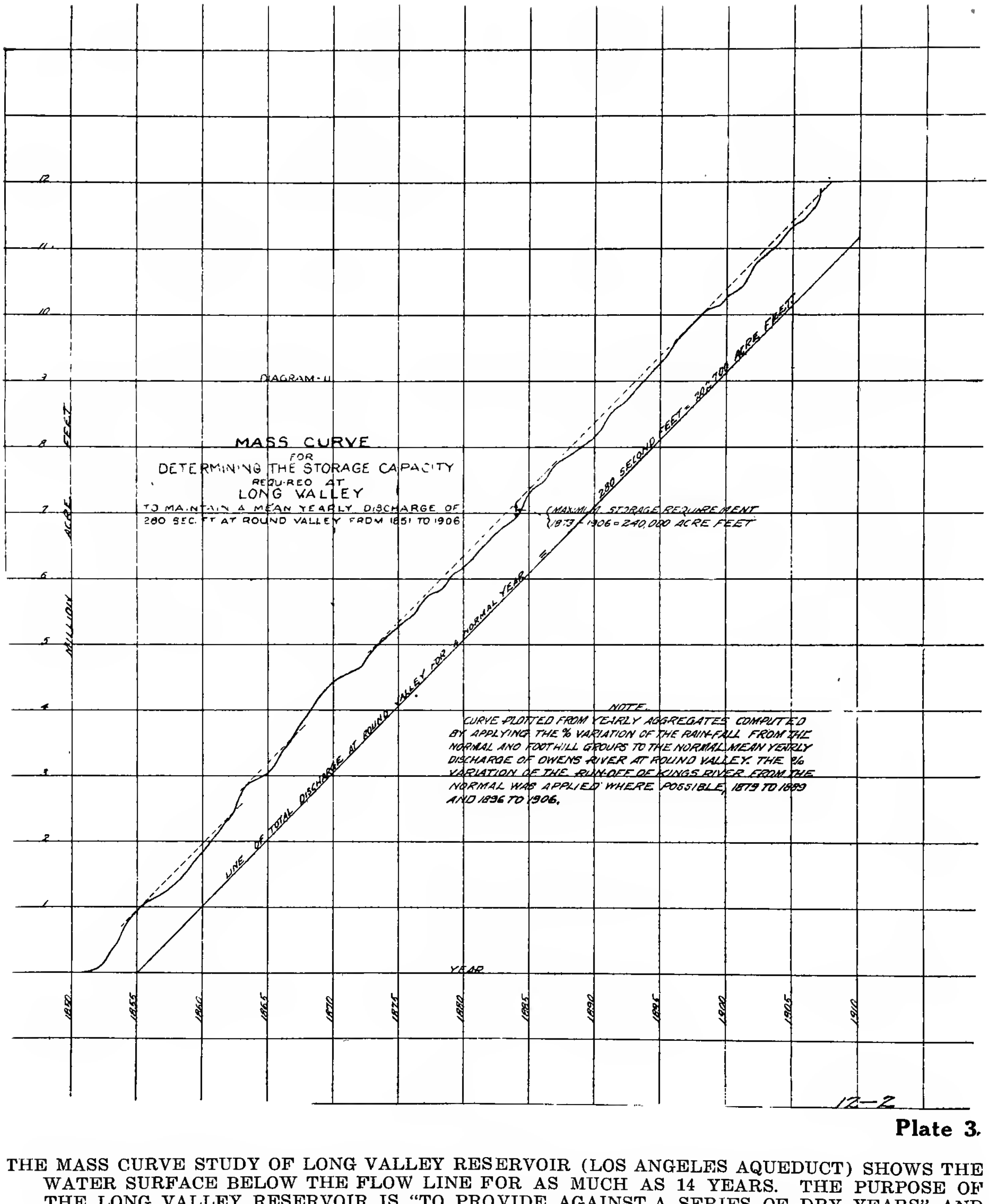


Plate 3.

THE MASS CURVE STUDY OF LONG VALLEY RESERVOIR (LOS ANGELES AQUEDUCT) SHOWS THE WATER SURFACE BELOW THE FLOW LINE FOR AS MUCH AS 14 YEARS. THE PURPOSE OF THE LONG VALLEY RESERVOIR IS "TO PROVIDE AGAINST A SERIES OF DRY YEARS" AND WAS APPROVED BY MESSRS. FREEMAN, STEARNS AND SCHUSSLER.

tributary catchment area was estimated backward as far as 1850, and a mass diagram, reprodution of which is shown on Plate 3, was made to determine the necessary storage to sustain the proper draft. This mass curve shows that a maximum storage of 240,000 acre feet is required, and *that the water surface in the reservoir would be continuously below the flow line for 14 years from 1873 to 1887, and again for 9 years from 1887 to 1896, and again for 9 years from 1898 to 1907.* This plan received the approval of Messrs. Freeman, Stearns and Schuyler.

Thus it is seen that the Long Valley Reservoir will have its water surface below the flow line for longer periods than any of the storage reservoirs of the Spring Valley Water Company.

Great Storage Available in Alameda System.

Within the Alameda catchment area are three large surface reservoirs which will be utilized in the development of the Alameda System, enumerated as follows:

Reservoir	Storage Capacity	Elevation
Calaveras	55,000 M. G.	800
San Antonio	11,674 M. G.	443
Arroyo Valle	13,830 M. G.	800
Total for surface reservoirs	80,504 M. G.	

These reservoirs and their value as water producers, will be described later in this report. In addition to these surface storage reservoirs, it is proposed to utilize two subterranean reservoirs —that at Sunol, commonly referred to as the Sunol Filter Beds, and that underlying the Livermore Valley, from which, at the present time, this Company is drawing up to 11 M. G. D. with but a single centrifugal pump.

Geologists Say Gravel Deposits in Alameda System Are Very Large.

These two gravel deposits cover very large areas and are exceedingly deep. By the unique actions of nature they are hemmed in on all sides by impervious rock, making them in effect two huge sponges which greedily absorb flood waters that would otherwise go to waste, and retain them until withdrawn by artificial means. These gravels have been the subject of very careful and extended examinations by Dr. J. C. Branner, Professor of Geology and Vice-President of Stanford University, and Dr. Andrew Lawson, Professor of Geology of the University of California, and reference is here made to the reports upon this subject by these two geologists. Both these scientists have international reputations, and are undoubtedly better equipped to determine the great water bearing capabilities of these gravels than any other men. Among other distinctions, Dr. Branner has recently been the recipient of the Hayden medal, which stamps him as the foremost geologist of his day, and both have gained renown in solving the mysteries of Western geology, the most intricate and complex in the world. Each has made an independent report and they agree that these gravel beds are probably the greatest of their kind in the world. They find that these gravels exist under practically the whole of the Livermore Valley for a depth of at least 4000 feet, and under the Sunol Valley for a depth of 500 to 1000 feet. Of course, we all know that in speaking of gravel the geologist means intermingling deposits of gravel, sand and denser materials, yet both attest to the enormous water carrying capacity of the gravels as a whole.

Dr. Branner and Dr. Lawson have used the term just as Dr. Crosby has used it in connection with the Long Island gravels and sands.

From borings both in the Livermore Valley and at Sunol, it appears that at Sunol the porous gravel and sand constitutes a much higher percentage of the entire mass than is the case at Livermore. It is estimated that the Valley fill at Sunol will have an available porosity of at least 25 per cent. The area of these gravels is, in round numbers 1300 acres. Therefore, if we figure on only an average depth of 100 feet in these gravels, their storage capacity becomes 10,000 M. G. It is physically practicable to deplete these gravels to a much greater depth by means of pumps, and in point of fact is being done in many places in California today, by several types of pumps, notable among them being the multiple stage centrifugal pump that operates inside the ordinary well casing, and the air lift pump.

Storage of Alameda System Aggregates Over 177,000 Million Gallons.

Similarly, the storage of the underground reservoir beneath Livermore Valley for the top 100 feet is estimated by assuming a percentage of porosity of 14 per cent as described later on in this report, and is found to be 87,000 M. G. The total storage in the Alameda system is, therefore, as follows:

	M. G.	M. G.
Surface Reservoirs:		
Calaveras	55,000	
San Antonio	11,674	
Arroyo Valle	13,830	80,504
Underground Reservoirs:		
Sunol	10,000	
Livermore	87,000	97,000
Total storage		177,504

This aggregate storage does not include that of the Pliocene gravels upon which Dr. Branner lays so much stress. That artesian wells whose source of supply is the Pliocene gravels will be found in the valley floor, is made certain by the fact that on the foothill slope near Pleasanton there already exist artesian wells in these same gravels. In this matter I have been conservative in that I have omitted the supply that may be obtained from wells supplied by these Pliocene gravels, and have not taken advantage of the enormous storage available below a depth of 100 feet, both of which it is practicable to realize.

Liberal Deduction Is Made for Evaporation from Reservoirs.

It is essential to provide for evaporation in estimating the safe yield from reservoirs.

From surface reservoirs evaporation proceeds continuously from the water surface. Measurements to determine the amount of this evaporation as well as its monthly distribution have been made in several parts of California, as well as in other parts of the United States. The subject is thoroughly discussed in Appendix "D", and for the purpose of this report the evaporation is taken as 48 inches per year, which in lieu of actual measurements at each reservoir site, is believed to be as nearly correct as can be obtained by comparison with measurements elsewhere. The evaporation from water surfaces is a loss that cannot be recovered in any way.

In deducting for loss due to evaporation credit should be given to the precipitation that falls upon the surface of the reservoir itself. The catchment tributary to a reservoir includes the area occupied by the reservoir, and in computing the run-off the same percentage of rainfall has been applied to both areas.

Deductions Are Excessive for Sake of Conservatism.

Manifestly *all* of the rain that falls upon the water surface of the reservoir is added to the stored water, and the water crop for that season should be increased by the difference between the run-off in inches as applied to the whole catchment area and the inches of rainfall at the reservoir. The most simple manner to account for this addition is to deduct it from the seasonal evaporation.

Taking the actual mean rainfall as recorded at Calaveras for the Calaveras reservoir, and the actual mean at Sunol for the San Antonio reservoir, both for the 23-year period during which I have actual stream measurements, I get the following:

	Mean of actual rainfall	Amount credited to run-off	Amount which fell on reservoir in excess of credits and should be added to the net draft	
Calaveras	26.42″	12.22″	14.20″	1.44 M. G. D.
San Antonio	22.22″	6.61″	15.61″	0.90 M. G. D.

From this it will be seen that the safe dependable yield of Calaveras reservoir should be about 1½ M. G. D. in excess of that given in this report, while that of San Antonio reservoir should be nearly one M. G. D. more than that given. For the sake of presenting conservative estimates, I have neglected these additions that rightfully should be made.

Great Loss by Evaporation from Saturated Soils near Pleasanton.

Evaporation to an even greater degree than from a water surface, proceeds from soil surfaces in various degrees of saturation. This is also discussed in detail in Appendix "D".

Appendix "D" has been prepared by Mr. T. W. Espy, Civil and Mining Engineer, who has had wide experience as manager of one of California's hydraulic mines, and who for several years was in charge of the hydrographic work and reconstruction of the Imperial Valley Irri-

gation Project, embracing 300,000 acres of land and about 1000 miles of canal.

This evaporation is pertinent to the underground reservoir in Livermore Valley, where by reason of the artesian pressure the water impounded in the gravel reservoir in seeking an outlet is forced upward through the denser materials in the western end of the valley commonly called the "clay cap". This causes the overlying soils to be in a state of saturation, from which a surprisingly large amount of water is lost by evaporation. That the source of this water is from the underlying gravels is manifest from the fact that in small, swampy spots, where this upward pressure has been relieved by means of a number of large shallow wells, the soil near the wells dried out sufficiently to cultivate.

This Loss Can Be Recovered and Used.

This loss is at present a constant draft upon the underground reservoir and is lost to any useful purpose. By keeping the plane of saturation at least 10 feet below the ground surface, evaporation from the soil surface will cease and the water heretofore lost in the air will be recovered and delivered in conduits for the use of the people of San Francisco. This is not mere theory, but has been accomplished in many parts of California, as for instance, near Chino, where large saturated areas were reclaimed and made tillable, and the recovered water used elsewhere for irrigation. In this act the benefit derived was twofold—first the wet lands were reclaimed; and second, other desert lands too dry for successful farming were irrigated and made to produce abundantly.

This Has Been Done on Large Scale in Southern California.

Similarly, just south of Los Angeles, 50,000 acres were relieved in a like manner from saturation due to the underground waters of the Los Angeles River, and where before there was nothing but waste, there now are 50,000 acres of very valuable property, and this, too, after the City of Los Angeles drew 45.0 M. G. D. from this same underground supply.

At the present time a project located about midway between Los Angeles and Long Beach, and of the same character as above described, is being constructed. It will cost upwards of $1,000,000, and has for its purpose the reclamation of 100,000 acres of land by unwatering a saturated area and irrigating lands with the water drawn therefrom.

Water May Be Stored by Artificially Soaking the Gravels.

To fully utilize the vast underground storage of the Livermore Valley it will be necessary to conduct some of the flood waters from their natural channels over broad areas of porous gravels. Measurements in the Arroyo Valle Channel indicate that water entered these gravels, even under the unfavorable conditions of the winter of 1911-1912, at the rate of 10 cubic feet per square foot of superficial area, per day, which with a porosity of 33 1/3 per cent gives a velocity of 30 feet per day. Naturally, therefore, with an increased superficial area, water will be absorbed much more rapidly by the gravels, and a larger percentage of the flood waters will enter them.

It is proposed to utilize sufficient superficial area, in conjunction with the Arroyo Valle Reservoir, and the present stream bed, so that very little water will escape into Laguna Creek and be wasted. Exception may be taken to this method of conservation because of fear that the gravels may become clogged up with silt, but let it be borne in mind that in the first place there is not a large amount of silt in these waters, and in the second place, their velocity is abruptly checked when they enter Arroyo Valle Reservoir, and they will drop whatever silt they carry into the bottom of this reservoir, before being conducted to the gravels.

Furthermore, the Arroyo Mocho has been spreading out over the gravels near Livermore for untold years, very rarely running through to the Laguna Creek, and there is no evidence of a decrease in the absorptive powers of these gravels by reason of its action.

This Is Being Done in San Bernardino Valley.

This practice of spreading flood waters over gravels has been in progress in San Bernardino Valley, in Southern California, for several years past. Just below where the flood waters of the

SPREADING THE FLOOD WATERS OF SANTA ANA RIVER TO INCREASE STORAGE IN GRAVELS.

Similar Methods Will Be Followed to Increase the Storage in Livermore and Sunol Gravels.

Santa Ana River debouch from the mountains, they are diverted by means of dam and canals and spread over the gravels of the stream bed, much in the same way that broad irrigation is practiced.

In this manner great quantities of flood waters are absorbed by the gravels, increasing the underground supply from wells for a distance of sixty miles below. Officers of the various companies profiting by this work, state that the increase is very marked, and that they are repaid a thousand fold for the expense incurred to spread the waters.

It is probable that the velocity with which the water enters the gravels in this case is about the same as it will be in the Livermore Valley. I visited the site of this work last year while the work of spreading water was under way and saw how greedily the gravels drank up the water. Even where water is spread in soils it is absorbed with surprising rapidity.

In Imperial Valley, while Chief Engineer of the California Development Company, I have many times observed water entering the soils at the rate of 1 to 3 feet per day in the dense clayey soils predominant in the greater part of that valley; and this with water that is notoriously muddy, carrying several thousand times the quantity of silt that the Arroyo Valle does.

As development proceeds it may be found necessary to handle the waters entering Sunol Valley in the method above described, though it seems probable that this will not be the case.

Calaveras Reservoir Is Largest in the Alameda System and Excellently Located.

Calaveras Reservoir, one of the largest in California, is located 36 miles from San Francisco and is the largest storage reservoir in the Alameda System. In the Calaveras Valley nature has provided a huge bowl 3 miles long and 1 mile wide, with a deep and narrow outlet at its northeasterly corner. The bowl offers a splendid opportunity to form a large lake, while the narrow outlet affords an admirable damsite whereby the lake may be readily formed.

As if appreciating the great opportunity and anticipating the necessity of large storage within easy reach of the people of San Francisco, nature also provided a large tributary catchment area where the run-off from ample snows and rains is conducted to the reservoir where it may be conserved for domestic use. The watershed of the catchment area directly tributary to Calaveras Reservoir covers an area of 98.3 square miles. The largest stream within its borders is the Hondo, which is formed by the junction of the Ysabel and Smith's Creeks, the last named streams passing around the east and the west flanks of Mt. Hamilton and its sister peaks which rise in lofty grandeur to an elevation of 4400 feet. In topography this area ranging from 550 to 4400 feet above sea level, is for the most part steep and rugged, broken by canyons leading to the main streams, and is largely covered with a dense mantle of trees and shrubs.

Precipitation in Calaveras Watershed Is the Greatest in the Alameda System.

Precipitation occurs both in the form of snow and rain. Snow very often makes the mountain inaccessible in the upper reaches and isolates the astronomers at Lick Observatory from direct contact with the world at large. Even in extremely dry seasons, as the one just past, there is a considerable snowfall, and intemperate weather is experienced.

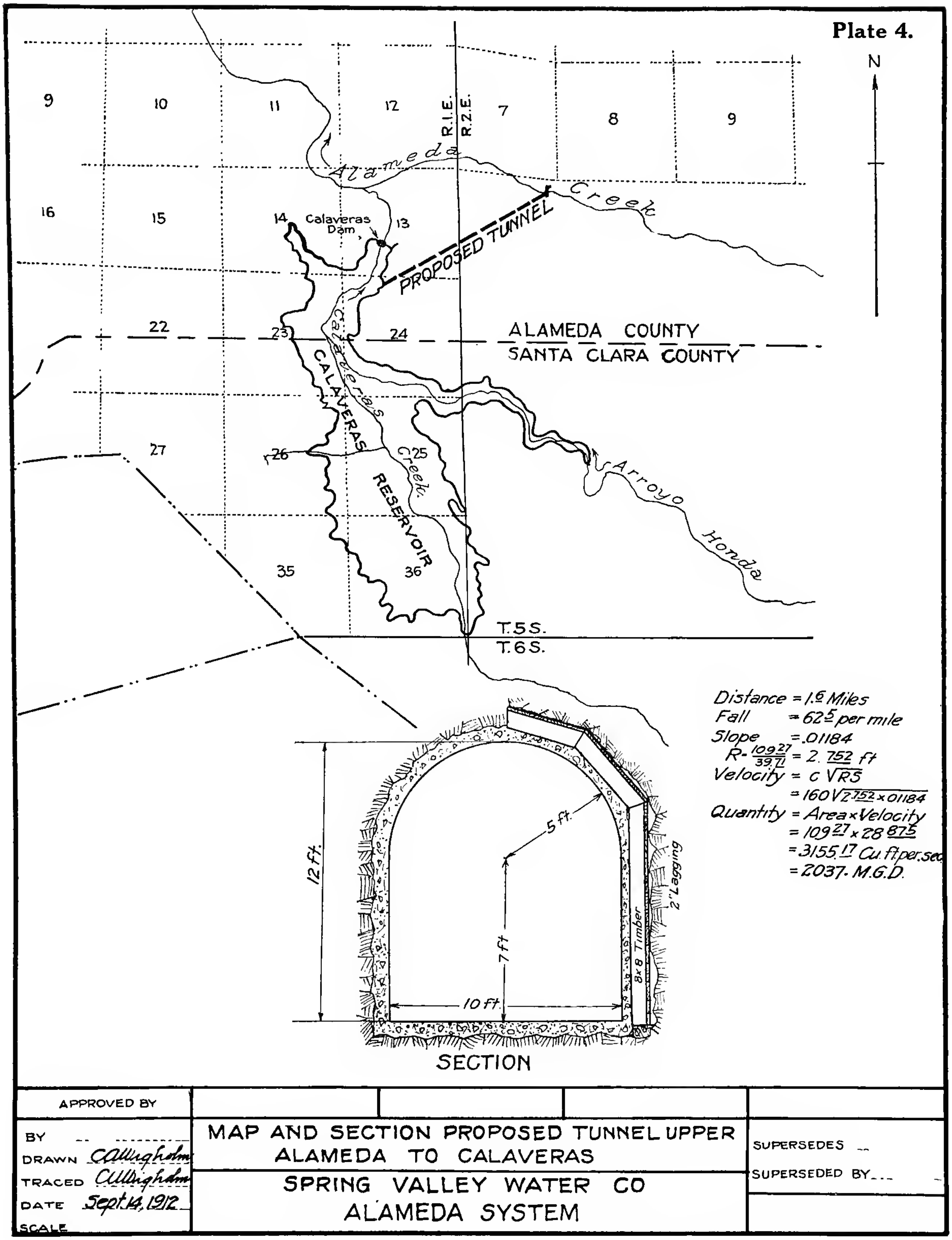
Record of precipitation has been kept at two stations within the Calaveras watershed—that at Calaveras for 38 years, and that at Lick Observatory on the crown of Mount Hamilton for 31 years. These records, when expanded by means of the San Francisco rainfall record, show a 63-year normal precipitation at Calaveras of 26.73 inches and at Mount Hamilton of 31.88 inches.

Many other short period records of precipitation have been taken within the watershed, notably the group of 15 given by Messrs. Haehl and Toll on page 534 of Volume 61 of the Transactions of the American Society of Civil Engineers.

These records for the most part cover periods of two years, and cannot be given the same weight as longer records. That they are probably too low is shown by the investigation of the late Col. Geo. Mendell, U. S. Army Corps of Engineers, who on page 815 of the Municipal Reports of San Francisco for the year 1876-77, says:

> "The stations were on Mt. Hamilton and on each side of it. The positions and altitudes are as follows:

THE HIGHER ELEVATIONS OF THE CALAVERAS WATERSHED.
High Mountains With Precipitous Slopes Insure a Rapid Run-off. Taken in the Dry Season of 1911-12.



THE WATER OF UPPER ALAMEDA CREEK WILL BE CONSERVED IN CALAVERAS RESERVOIR.

"No. 1—In valley of Smith's Creek at western foot of Mt. Hamilton. Altitude 1,950 feet.

"No. 2—Western flank of Mt. Hamilton. Altitude 3,000 feet.

"No. 3—Eastern flank of Mt. Hamilton. Altitude 3,450 feet.

"No. 4—Isabel Valley at the eastern foot of Mt. Hamilton. Altitude 2,250 feet.

"No. 5—On flank of mountain on east side of Calaveras Creek, and four miles north of Mt. Hamilton. Altitude 2,200 feet.

"No. 6—On the western flank of the western mountains bounding Calaveras, therefore not in Calaveras Valley, but to the west of it. Altitude 1,450 feet.

"The observations show very clearly that the rainfall in the Calaveras basin is in excess of that on the western flank facing Santa Clara. They also appear to indicate no greater fall on the mountains than in the valley. On the contrary, Isabel Valley gives a greater fall than any point above it."

All Rainfall Records Expanded to Sixty-three Years.

For the purpose of this report and to be conservative in the estimated safe yield, these records have been expanded to 63 years, and, together with other records, form the basis of the isohyetal lines shown on Plate A-2. In addition to these records I have obtained two records of precipitation on the ridge dividing the Hondo and the Upper Alameda about 12 miles northwest from Mount Hamilton, for the season 1911-1912. These records indicate that along this ridge the precipitation is nearly, if not quite, as high as that around Mount Hamilton. From these various rainfall records, which are fully discussed in detail in Appendix "A", the mean areal precipitation of the Calaveras watershed is found to be 28.55 inches per season. The minimum areal rainfall is 9.53 per season, and the maximum is 47.67 inches per season. Examination of the daily precipitation record shows wide divergence in its occurrence and intensity. At Calaveras the maximum recorded daily precipitation is 3.60 inches. 14.94 inches of rain have fallen in one month and 25.12 inches in two months. These are, of course, very favorable conditions for high rate of run-off.

Large Quantities of Water Pass Down Calaveras Creek.

The run-off from the Calaveras catchment area is discussed in detail in Appendix "B". Actual run-off measurements are available for the seasons of 1898-99 to 1907-8 and 1910-12. These measurements show that while in summer the flow may get as low as 1 cubic foot per second, in winter floods upward of 12,000 cubic feet per second occur. At the present time these floods go to waste and contribute their share to the destruction in the lower lying lands. When the Calaveras Reservoir is completed this destruction will in part cease and the flood will become a useful agent in supplying the people of San Francisco with pure, wholesome water.

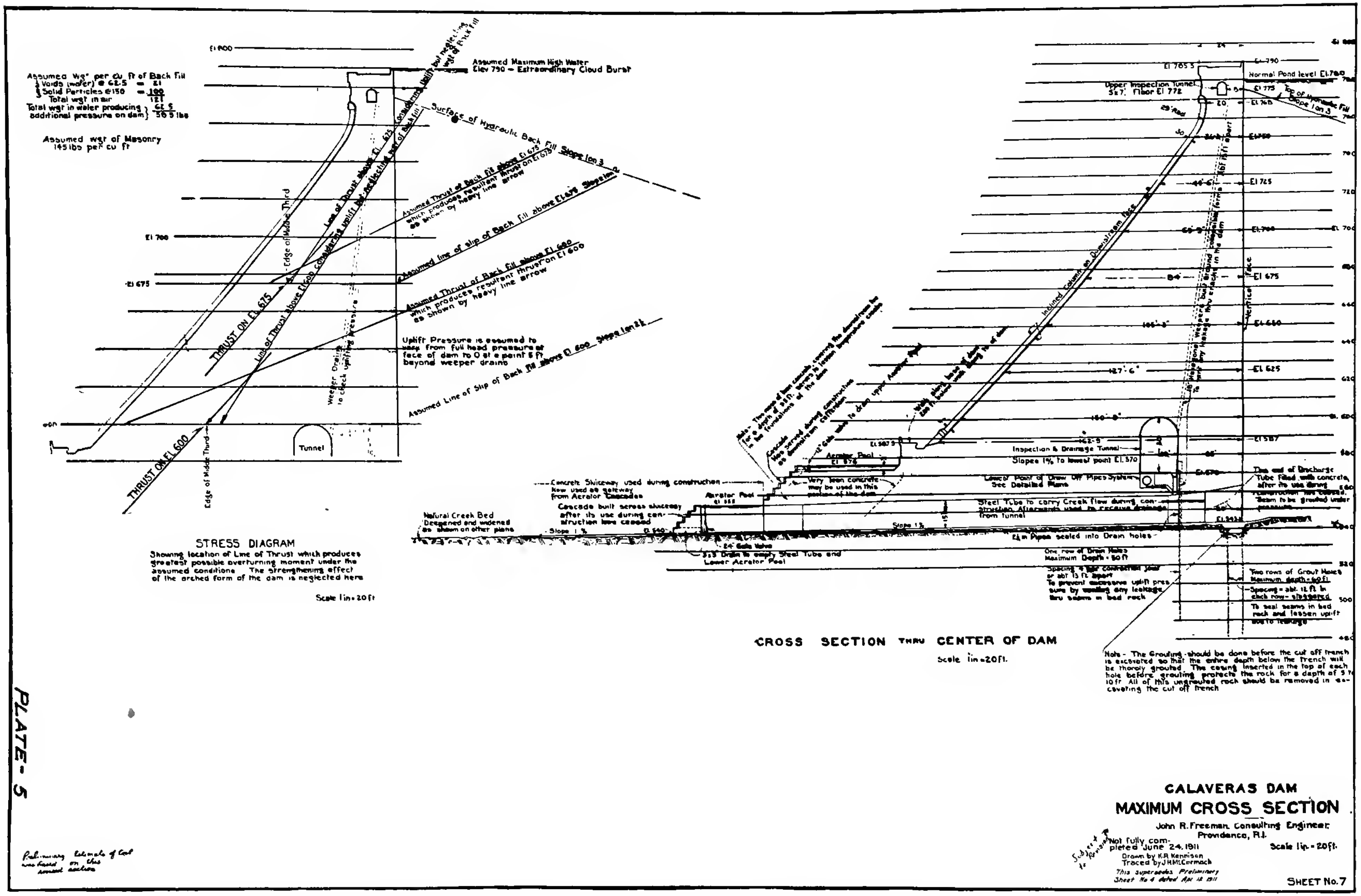
By the use of the run-off curves as developed in Appendix "B" and shown on Plates B-1 and B-6, run-off from the Calaveras catchment area has been estimated for each of the seasons from 1849-50 to 1911-12 where actual measurements are not available.

The Upper Alameda Will Be Diverted into Calaveras Reservoir.

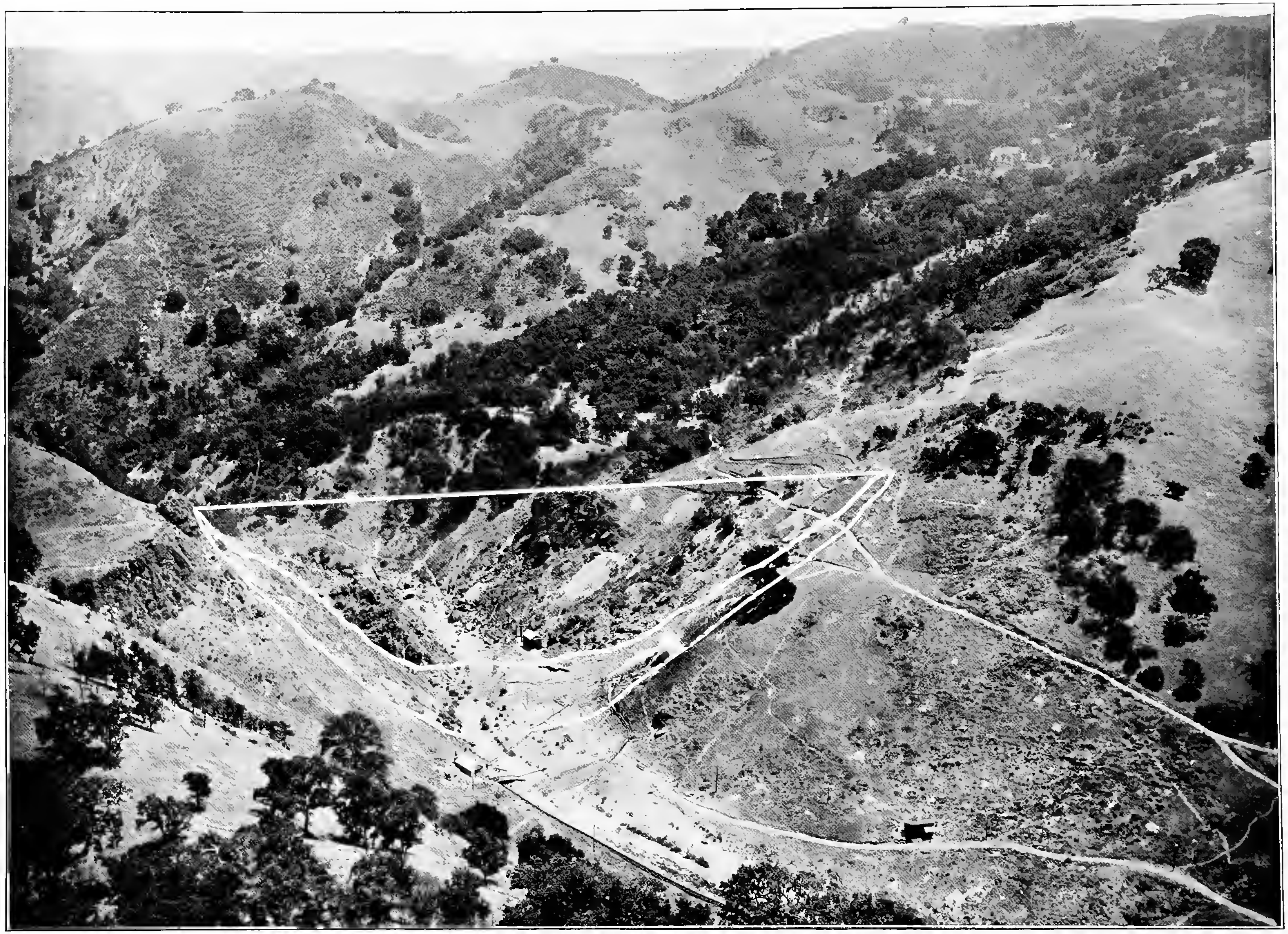
The Upper Alameda Creek is in the next catchment area lying directly northeast of the Calaveras area, and joins the Calaveras Creek just below the gorge in which the Calaveras dam is located.

By means of a tunnel 1½ miles long, the waters from the upper 35.32 square miles of the Upper Alameda will be diverted and delivered into the Calaveras Reservoir, as shown on Plate 4. Like that of the Calaveras, the catchment area of the Upper Alameda is picturesque in its ruggedness and is blessed with a high precipitation. Though less than half the size of the Calaveras watershed, the Upper Alameda resembles it in many ways, and particularly as to rate of run-off. Reliable measurements of the flow of Alameda Creek are available only for the season of 1911-1912 and for a portion of the season of 1910-1911. Prior to 1910 a few scattering measurements of floods were taken by Mr. Cyril Williams, Jr., simultaneously with the measurements he took at Calaveras. These are very crude, however, and are probably too high, as was found to be the case with those he made at Calaveras.

From the determination of precipitation and run-off of the Upper Alameda, as found in Appendices "A" and "B", the probable flow of



REPRODUCTION OF MR. FREEMAN'S DESIGN OF THE CALAVERAS DAM FOR THE SPRING VALLEY WATER COMPANY
Provides for a Maximum Storage of 52,500 Million Gallons and a Normal Storage of 46,300 Million Gallons.



CALAVERAS DAMSITE.
The Outlines of the Calaveras Dam Recommended by Mr. J. R. Freeman. Note the Narrowness of the Gorge at the Damsite.

Alameda Creek for each season of the period 1849-50 to 1911-12, has been computed.

Plans for Calaveras Dam Have Been Considered Since 1875.

Plans for the construction of Calaveras Dam have been proposed by different engineers at various times since 1875, and extensive explorations have been made to determine the proper location, and character, and depth, of bed rock. All the earlier designs called for a dam about 150 feet high. Finally the design of an earthen dam 220 feet high, together with the available exploration, hydrographic and meteological data and topographical maps of the reservoir and damsite, were submitted for approval to Mr. J. R. Freeman, an eminent authority on the design of dams, by the officers of the Spring Valley Water Company. These plans did not meet with Mr. Freeman's approval, and, at his own suggestion, in April, 1911, he presented to the officers of the Spring Valley Water Company a preliminary design of a combined concrete and earthen dam having a height of 250 feet, as a substitute for the design previously submitted to him. He recommended further exploration because the location of the dam proposed by him differed somewhat from the location of that submitted to him. (See Plate 5.)

Plans of Calaveras Dam Prepared by Freeman.

In June, 1911, construction on the Calaveras Dam, according to the Freeman preliminary design, was begun by stripping the loose material from the canyon wall with a hydraulic monitor. When the stripping of the east abutment was well under way Mr. Freeman again visited the damsite, examined the bed rock conditions, expressed himself as well satisfied with them, and instructed me to strip the abutments 10 feet higher, as it was his intention in his final design to increase the height of the dam in his preliminary design by that amount, making a total height of 260 feet.

The Storage Capacity of Calaveras Reservoir.

Comparing these various designs and the physical data relating to each, we have:

Design.	Height.	Length. on top.	Storage capacity of reservoir.
Presented to Freeman for approval	220 ft.	875	30,500 M. G.
Freeman's preliminary design	250 "	900	46,300 " normal 52,500 " maximum
Freeman's final design	260 "	940	52,500 " normal 58,300 " maximum

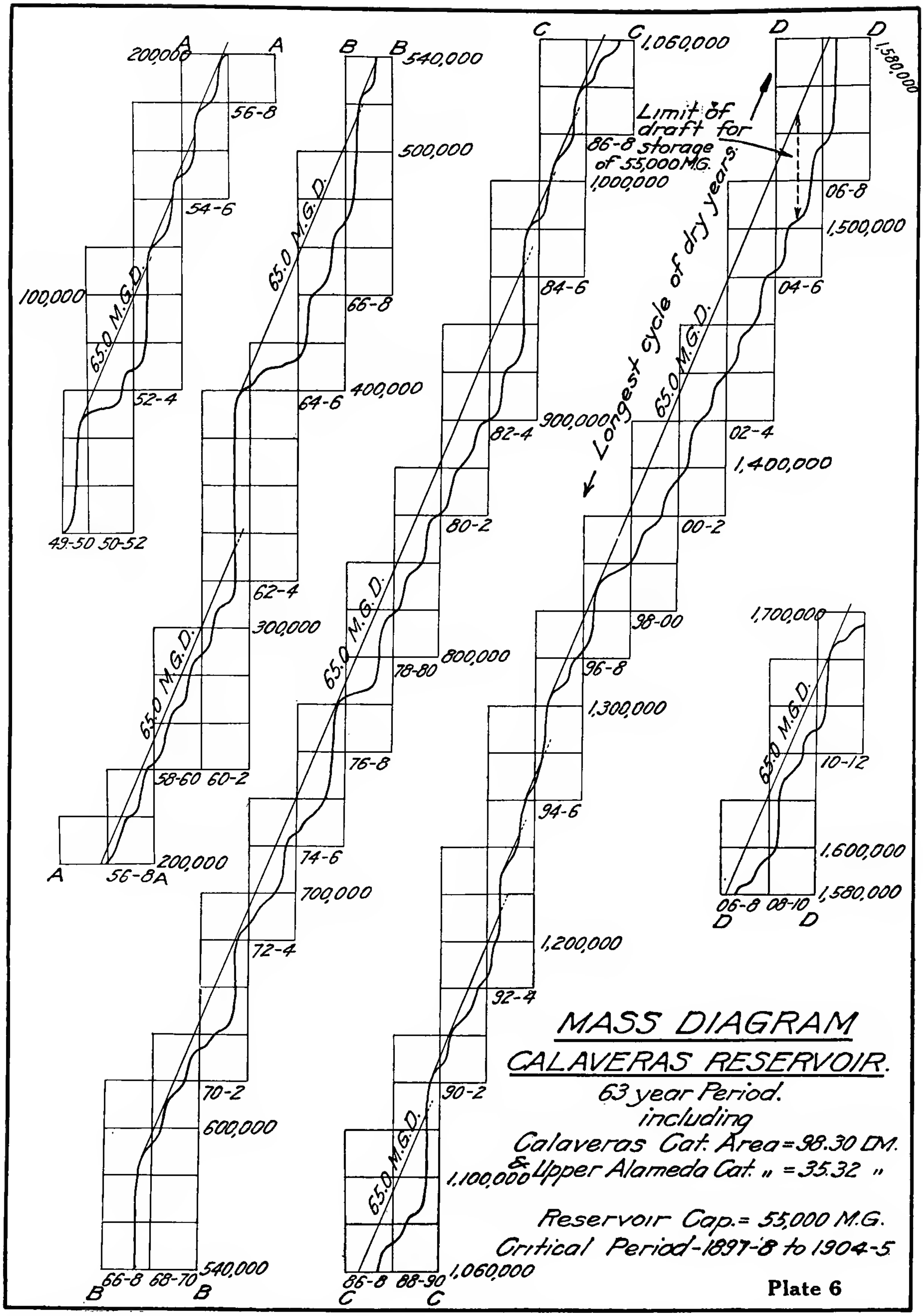
The storage that will obtain under the Freeman final design has been used for the purpose of this report. It is proposed to have the normal flow line 10 feet below the crest of the dam, arranged in such a way, however, that the 5 feet above the flow line may be utilized when necessary, making the water surface at such times 5 feet below the crest of the dam.

Thus while the storage capacity at the normal flow line is 52,500 M. G., its storage capacity that may be used when necessary is 55,000 M. G., and if used in the same manner as proposed by Mr. Freeman in his preliminary plan, the water surface in case of a cloudburst may be level with the crest of the dam, in which case the storage becomes 58,300 M. G.

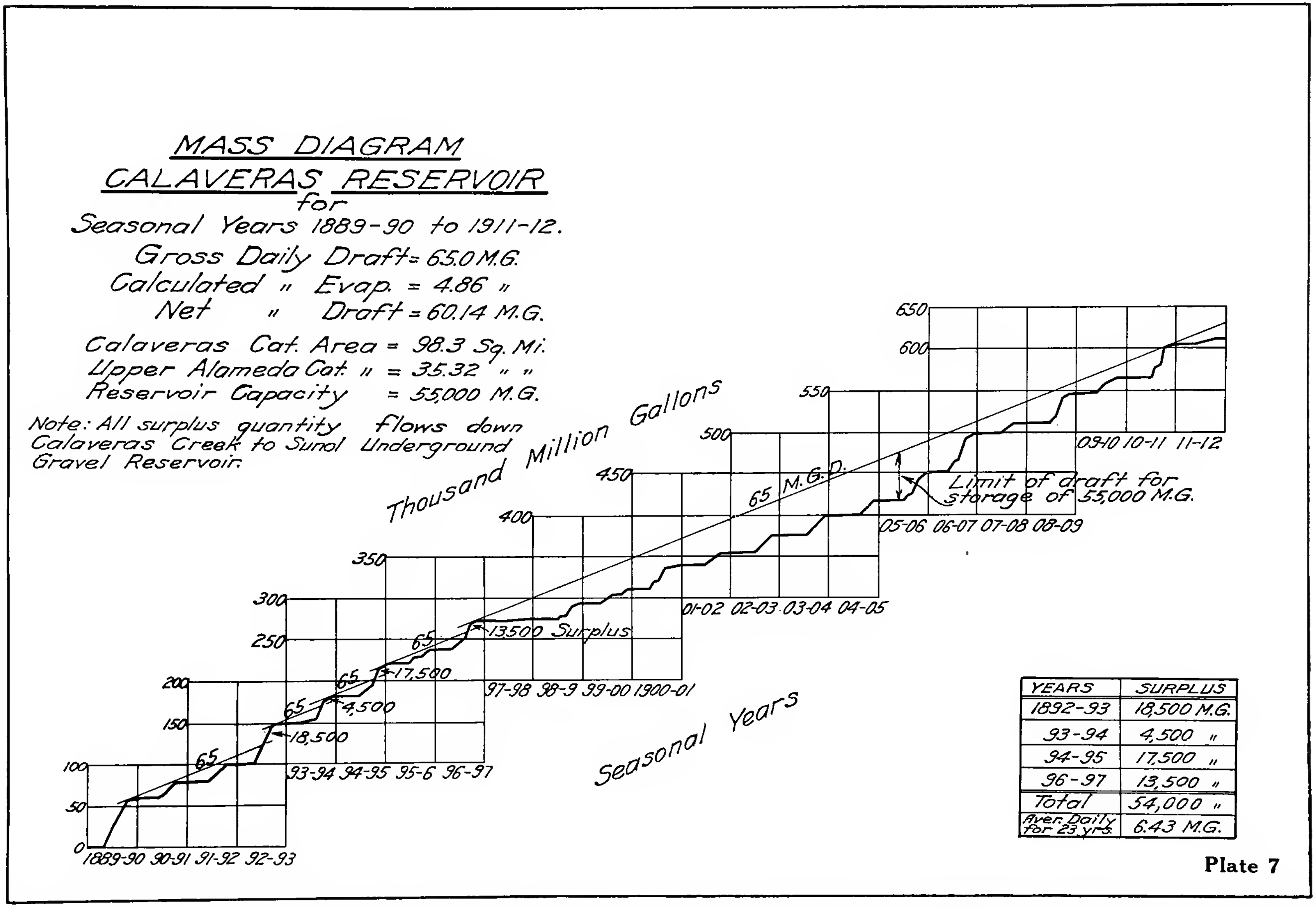
The Calaveras-Alameda Tunnel Designed to Carry Extreme Floods.

As above explained, the purpose of this tunnel is to deliver water from the Upper Alameda into the Calaveras Reservoir. It must be comparatively large to accommodate the floods of the Upper Alameda. Measurements of Upper Alameda floods are very few in number. There were no large floods in the season of 1911-1912, though in 1910-1911 we have record of what is probably a maximum flood. This flood, at its peak, was running at the rate of 2100 million gallons per day.

I have designed a tunnel connecting the Upper Alameda with the arm of the Calaveras Reservoir that extends up the Hondo. With a grade of 62½ feet per mile, this has a capacity of over 2000 M. G. D. A small reservoir will be created by the diversion dam in the Upper Alameda, which will act as a regulator, and by reason of the fact that the peak of the high floods lasts but for a few hours, there is every reason to believe that practically all the waters of the Upper Alameda will be stored in the Calaveras Reservoir. Even though the peaks of extreme floods do escape, the loss will not exceed 1% of the total run-off.



LONGEST CYCLE OF DRY YEARS OCCURRED DURING LAST 23 YEARS. MEASUREMENTS OF STREAM FLOW IN THE ALAMEDA SYSTEM COVER THIS PERIOD.



CALAVERAS RESERVOIR WILL SAFELY YIELD OVER 60 MILLION GALLONS DAILY SHOWN BY 23-YEAR RECORD DURING WHICH ACTUAL MEASUREMENTS OF ALAMEDA CREEK WERE TAKEN.

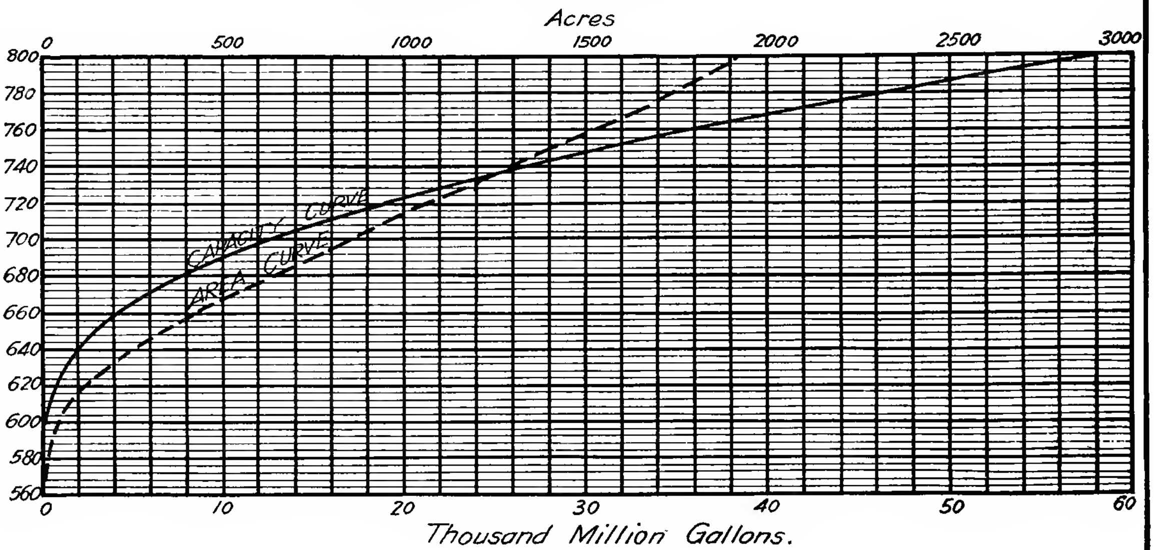
Plate 8

CALAVERAS RESERVOIR

Capacity and Area

Contour Elevation	Area in Acres	Capacity in M.G.
560	0.37	0.00
580	11.2	37.70
600	33.7	183.93
620	123.8	697.67
640	261.0	1951.70
660	418.0	4165.78
680	643.0	7623.41
700	845.0	12474.19
720	1078.0	18744.30
740	1291.0	26465.53
760	1531 0	35665.93
780	1736.0	46315.58
800	1930.0	58257.40

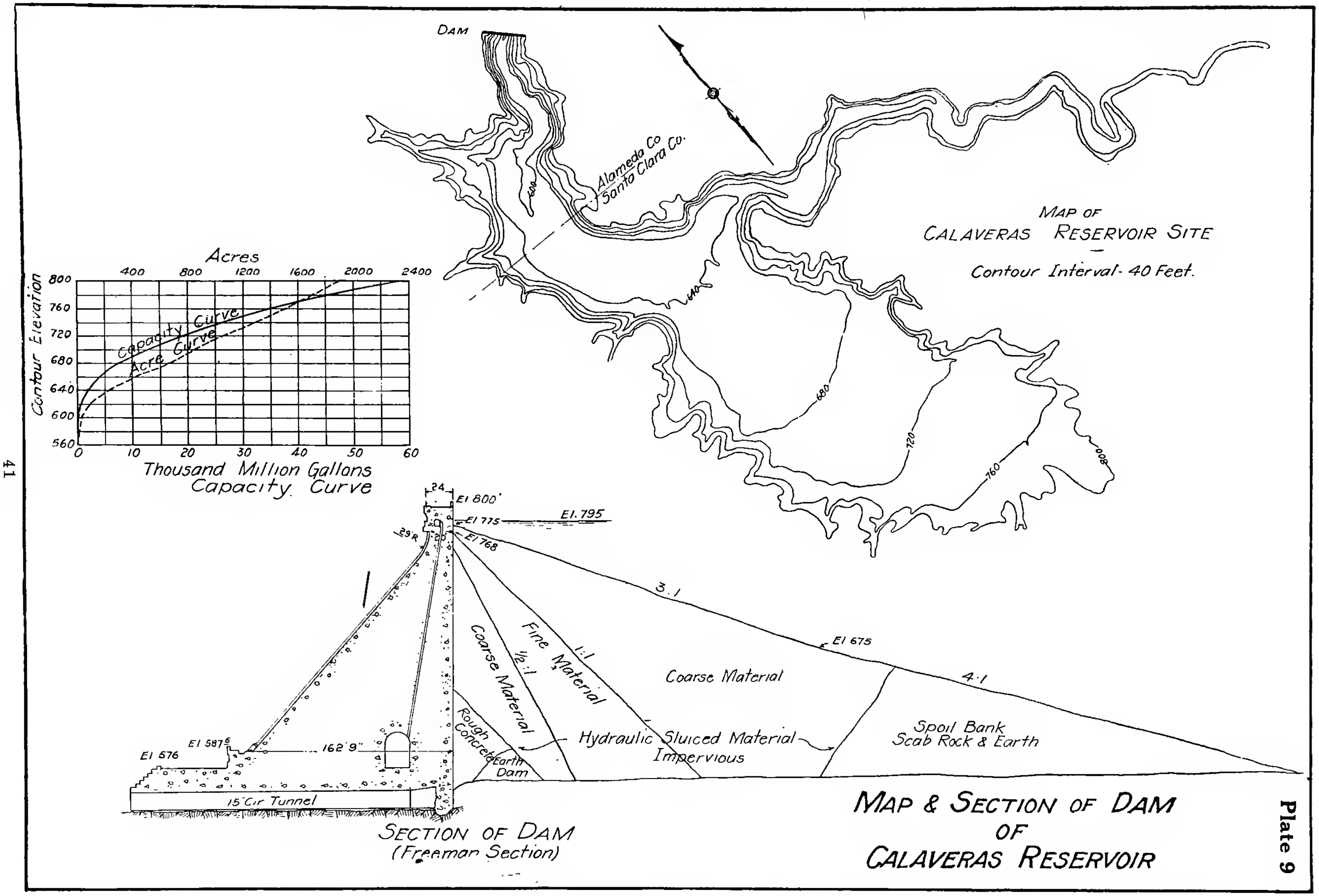
Crest of Dam - Elev 800'
Max. Water Height Elev 795'
Capacity 55,000,000,000 Gals.



Calculations from Map F-81 | Crystal Springs Datum.

APPROVED BY				
BY A.J. Krutmeyer DRAWN " TRACED C.Allighohm DATE Sept. 13, 1912 SCALE	CAPACITY AND AREA CURVES CALAVERAS RESERVOIR SPRING VALLEY WATER CO ALAMEDA SYSTEM			SUPERSEDES SUPERSEDED BY

SHOWING THAT WHEN THIS DAM IS BUILT TO THE HEIGHT PROPOSED BY J. R. FREEMAN IT WILL CONTAIN FOR SAN FRANCISCO NEARLY TWICE THE STORAGE OF ALL THE PRESENT LAKES OF ITS SUPPLY.



TOPOGRAPHICAL MAP OF CALAVERAS RESERVOIR AND PRELIMINARY PLAN OF DAM, DESIGNED BY J. R. FREEMAN.

Note the remarkable combination of ideal dam site and great reservoir capacity, which will serve San Francisco by gravity with 60 M. G. D. and only 40 miles from San Francisco. This will be one of the largest reservoirs in the West.

The Calaveras Reservoir Will Safely Yield Over 60 Million Gallons Daily.

In computing the safe yield of the Calaveras Reservoir I have therefore used the combined catchment areas of the Calaveras proper, and the Upper Alameda as a feeder, aggregating 133.62 square miles.

By combining the run-offs where actual measurements are available and the estimated run-offs as determined in Appendix "B", we are enabled to construct the mass diagram shown on Plate 6, giving the approximate run-off at Calaveras for a period of 63 years.

From this diagram it is seen that the most severe test on the draft from the reservoir occurs during the 23-year period in which records of run-off from the Alameda System are available.

By reason of this another mass curve has been made, Plate 7, on which is shown cumulatively the run-off at Calaveras for the last 23 years. Of the 23 seasonal records massed in this diagram, 12 are actual measurements, while the others have been ascertained by much more accurate methods than those used for the 63-year mass curve, the latter being merely an index to show where the most severe test shall be applied.

Using the maximum storage of Calaveras Reservoir in accordance with Mr. Freeman's final plans, the draft line for the safe continuous gross draft from this reservoir is found in this mass curve to be 65 M. G. D. After deducting for evaporation from the lake surface at the rate of 48″ per year (see Appendix "C") the safe net withdrawal from the Calaveras Reservoir by utilizing the combined catchment areas of the Calaveras and Upper Alameda (133.62 square miles) is found to be 60.14 M. G. D., which alone is approximately 70% greater than the present daily consumption of San Francisco.

From the mass diagram, Plate 6, showing the summation of approximate flow for the 63-year period, it is seen that prior to 1889-90 surplus would probably have occurred five times, as follows:

Season.	Approximate surplus, M. G.
1861-62	17,000
1867-68	30,000
1868-69	12,000
1869-70	4,000
1871-72	4,000

The waste in 1867-8 is far in excess of that which would have occurred in the other years.

By reference to the mass diagram, Plate 7, for the period 1889-1890 to 1911-12, during which we have actual measured run-off and rainfall data in the Alameda Watershed covering a period of 23 years upon which to compute more closely the seasonal run-off, it is seen that there would have been a surplus of water four times, and disregarding this surplus the reservoir would be again full after the floods of 1910-11. At these four periods the surplus water would have been as follows:

Season.	Approximate surplus, M. G.
1892-93	18,500
1893-94	4,500
1894-95	17,500
1896-97	13,500
Total	54,000

This surplus has not been included in the estimate of the dependable draft from Calaveras Reservoir. Distributed over the 23 years it amounts to about 6.4 M. G. D.

The surplus water above shown will flow down Calaveras and Alameda Creeks to the Sunol Valley, where it will assist in sustaining the draft from the Sunol Gravel Reservoir.

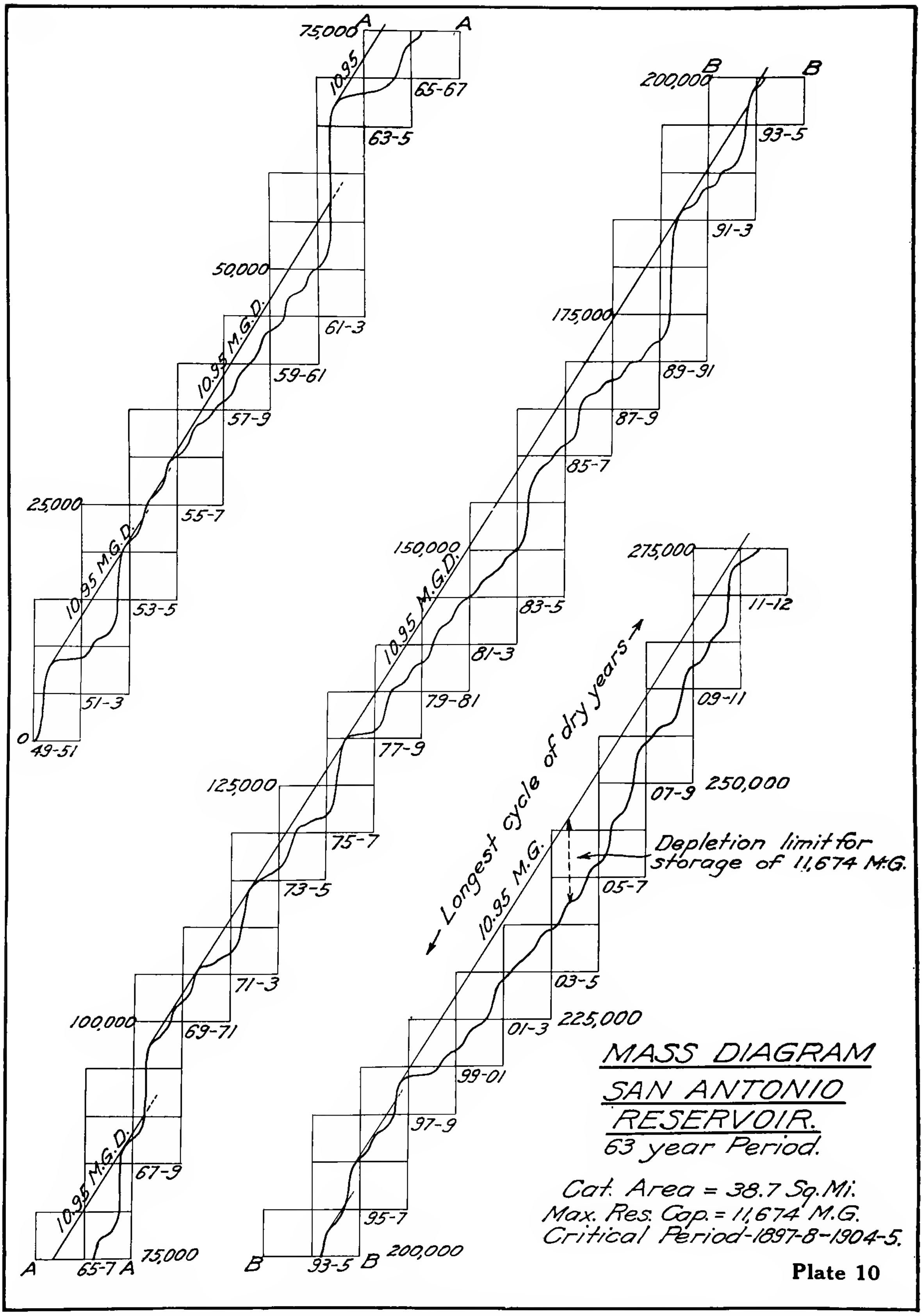
From this mass diagram it will be noted that the reservoir would be just empty at the beginning of the floods of 1905-6 and full again at the end of the floods of 1910-1911. In the summer of 1912, following the remarkably dry winter of 1911-1912, the reservoir would still be about ¾ full.

The relation between the catchment area of 133.62 square miles and the storage in the Calaveras Reservoir is almost ideal, as, even excluding the surplus water, about 92½% of the total run-off is conserved. Rarely is such an extensive and favorable reservoir site available below such a large and productive catchment area and in such proximity to a metropolis.

Plate 8 shows the storage capacity and area of water surface for different depths in the Calaveras Reservoir. Plate 9 shows a topographical map of Calaveras Reservoir and section of dam.

San Antonio Reservoir Favorably Located with Regard to Sunol Gravels.

The San Antonio Reservoir is located on the



BY INSPECTION IT IS SEEN THAT THE LONGEST CYCLE OF DRY YEARS IN 63 YEARS OCCURS WITHIN THE 23 YEARS OF ACTUAL GAGINGS AT NILES AND SUNOL.

Catchment Area = 38.7 Sq. Mi.
Max. Reservoir Cap. = 11,674 M.G.

Gross Daily Draft = 10.95 M.G.
Calculated " Evaporation = 2.03 "
Net " Draft = 8.92 "

YEAR	SURPLUS
1892-93	900 M.G.
93-94	1,100 "
94-95	2,800 "
96-97	300 "
Total	5,100 "
Aver. Daily for 23 yrs.	6.08 M.G.

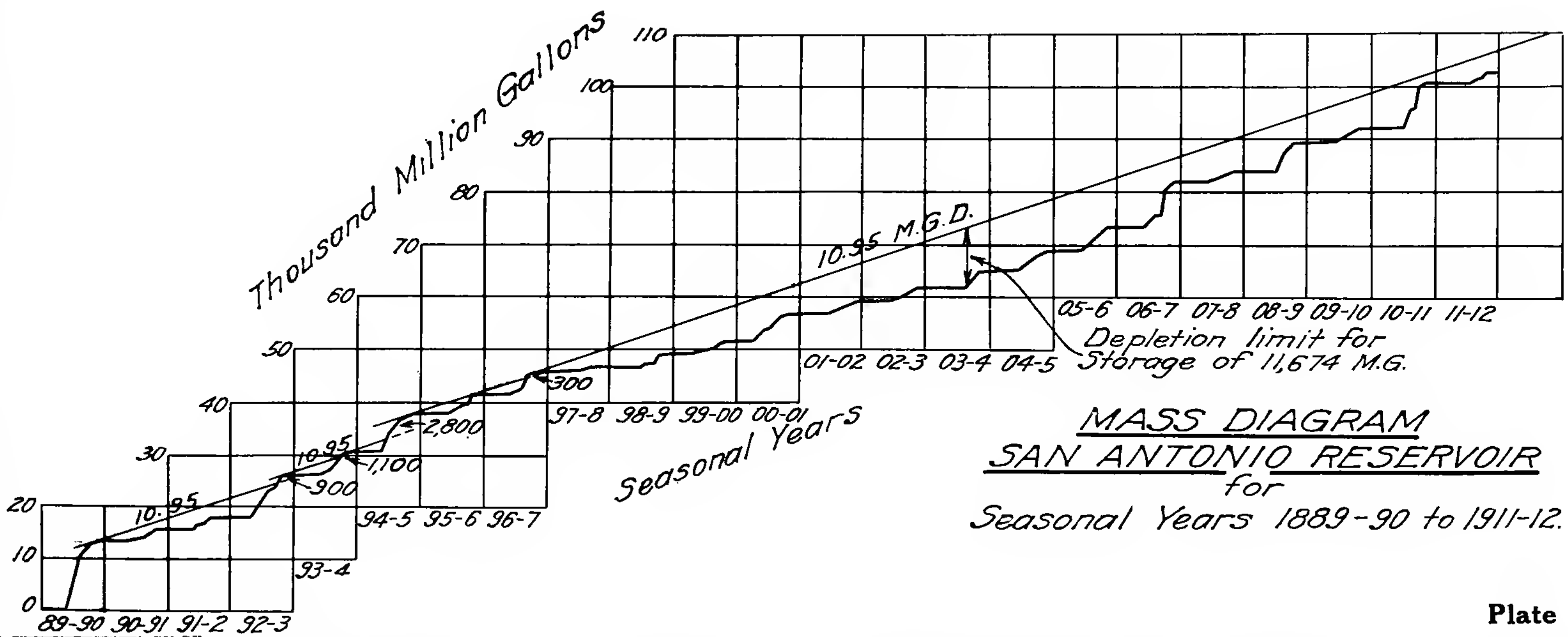


Plate 11

SAN ANTONIO RESERVOIR SUPPLY WILL BE FILTERED THROUGH SUNOL GRAVELS.

San Antonio Creek, a branch of the Alameda Creek, the confluence of which is about 1 mile above Sunol. The reservoir itself is located about 2½ miles from Sunol, with an elevation of 450 feet above sea level. It occupies the La Costa Valley and its proximity to the Sunol gravels and gathering point of all the waters of the Alameda System, lends an additional value to this reservoir.

While treated in this report purely as a storage reservoir, it will, when constructed, be operated largely as a regulating reservoir in conjunction with the Sunol Gravel Reservoir. In this manner its efficiency, together with that of the Gravel Reservoir, will be greatly increased.

Catchment Area.

Its tributary catchment area ranges from about 500 to 3800 feet in elevation above sea level, and is not so uniformly rugged nor as well covered with trees and shrubs as are the Calaveras and Upper Alameda catchment areas. On its north side are gently rolling hills, while on its south the mountains are bold in outline, culminating in Maguires Peak, which has an elevation of 3800 feet above sea level. To the east rises abruptly the main range dividing the waters of the Calaveras from those of the Arroyo Valle. Its watershed encloses a catchment area of 38.7 square miles. The only stream of size entering the San Antonio Reservoir is the San Antonio Creek, the waters of which now disappear into the Sunol Gravels, except in floods, and in this sense the San Antonio Creek is at present a tributary to the Sunol filter beds.

Precipitation.

Precipitation over the catchment area occurs mostly in the form of rain, though the high peaks to the south are often covered with snow. The station nearest San Antonio Reservoir where precipitation records have been kept is at Sunol, where rainfall has been measured for 23 years.

In Appendix "A" the mean seasonal areal precipitation for the San Antonio catchment area is found to be 23.93 inches, with a minimum of 7.86 inches, and a maximum of 50.71 inches. The seasonal areal precipitation is tabulated in Appendix A.

The regimen of the San Antonio Creek is similar to that of the Calaveras and Upper Alameda. During the wet season of the year it is often a torrent, while during the summer time its flow diminishes to a small stream.

Run-off.

Run-off records of the San Antonio Creek are available only for the flood periods of 1905-6, and for the last half of the season of 1911-1912. Run-off curves for San Antonio catchment area have been constructed and are shown in Appendix "B" on plates B-2 and B-6. By combining these curves with the areal rainfall, as given in Appendix "A", the probable flow of San Antonio Creek for each season during the period 1849-1850 to 1911-1912 has been computed.

Storage Capacity of San Antonio Reservoir May Be Increased When Necessary.

The present design of the San Antonio Dam calls for an earthen structure 145 feet high, creating in the San Antonio Reservoir a storage of 11,674 M. G. Explorations have been made determining the character and position of bedrock. These are excellent, and should it be found desirable at some future date to increase the height of the dam, it may be done in all safety to the limit of height for this type of structure.

San Antonio Reservoir Will Safely Yield Nearly 9 Million Gallons Daily.

To determine the safe yield of the San Antonio Reservoir, the probable run-off for the 63 years' period is shown cumulatively in the mass diagram, Plate 10. From this, as in the case of the Calaveras, the period which, together with available storage, largely determines the safe draft occurs within the last 23 years where we have actual measurements of run-off. The run-off of San Antonio Creek, as more closely determined for these 23 years where run-off measurements are available in the Alameda System, is shown on mass diagram, Plate 11. Upon this mass diagram is indicated the safe continuous draft that may be made upon this reservoir with due consideration for the available storage.

Reference to this diagram reveals that surplus water beyond what is necessary for a full

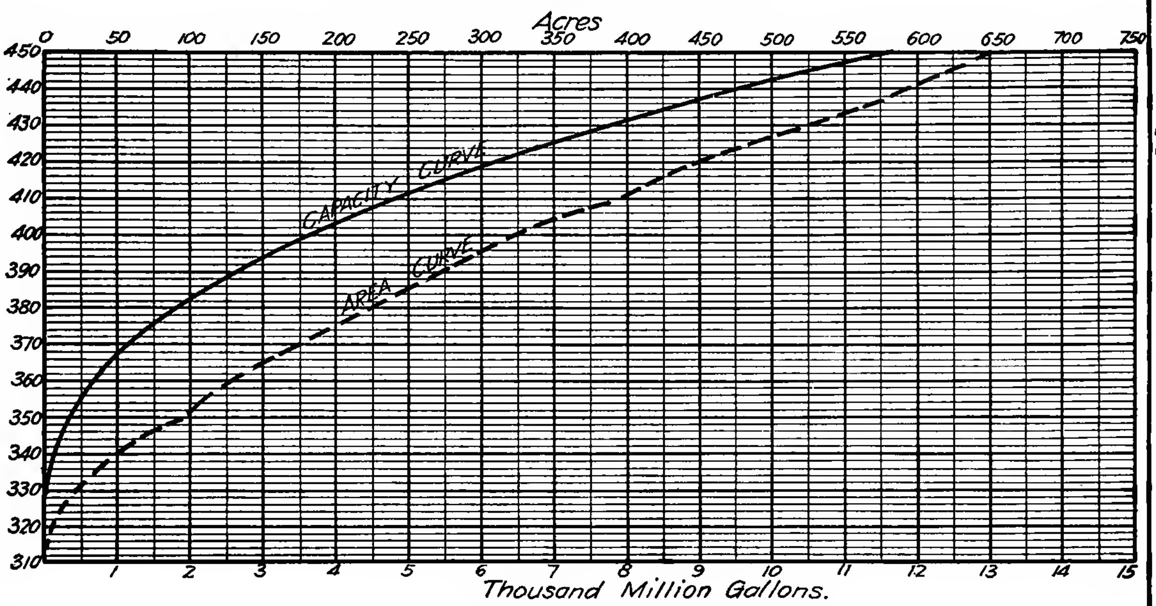
Plate 12

SAN ANTONIO RESERVOIR

Capacity and Area

Contour Elevation	Area Acres	Capacity in M.G
310	0.0	0.0
320	6.2	10.1
330	21.4	55.0
340	45.0	163.3
350	84.0	373.0
360	128.0	712.0
370	176.5	1208.1
380	222.8	1934.1
390	269.9	2661.4
400	331.6	3641.4
410	394.1	4823.7
420	453.6	6204.8
430	529.7	7806.9
440	594.2	9638.0
450	656.0	11,674.9

Crest of Dam - Elev. 450'
Max. Water Height Elev. 450
Capacity - 11,674,000,000 Gals

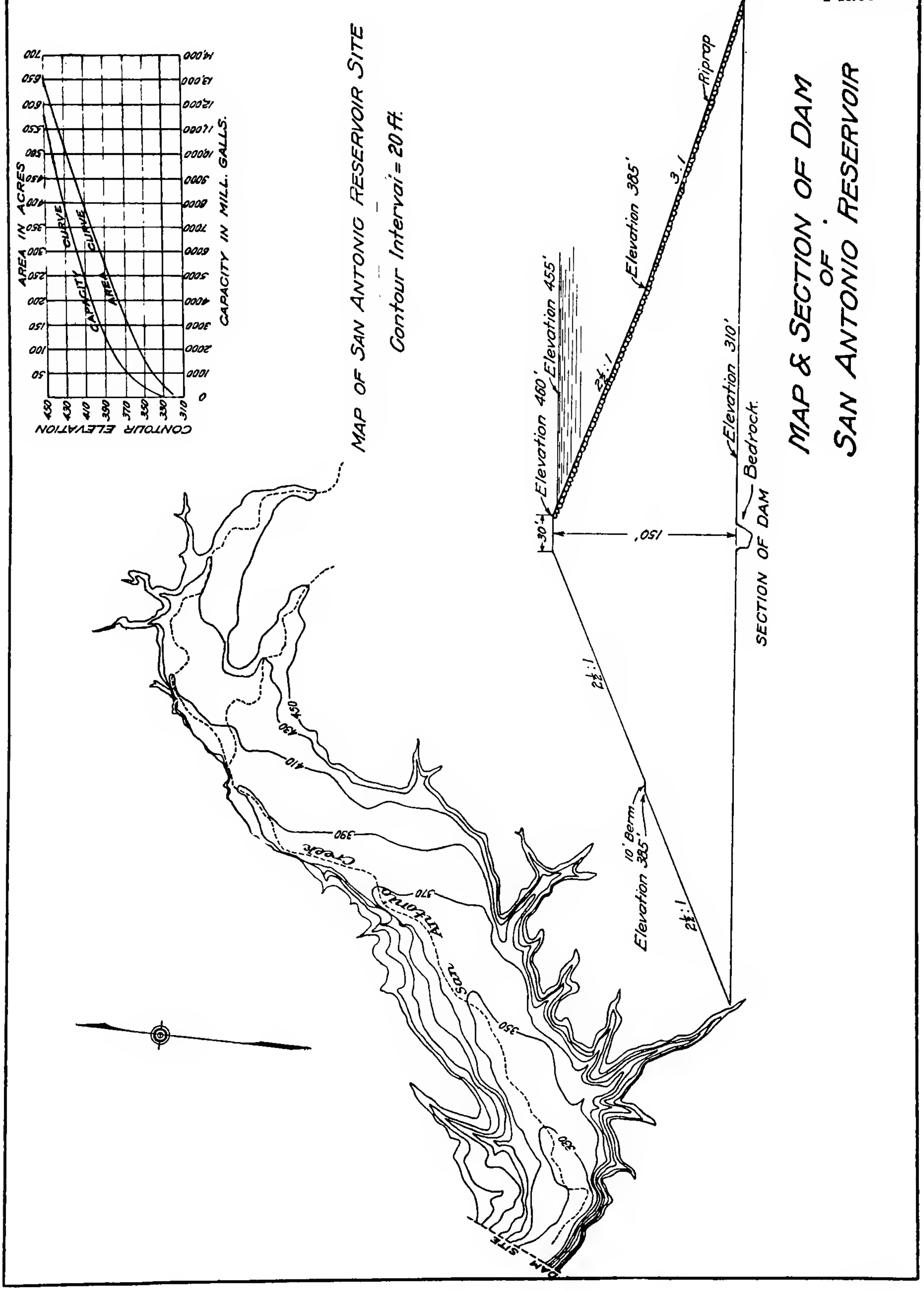


Calculations from Map F-53 Elevation Shown-minus 6.76' = C.S. Datum.

APPROVED BY				
BY A.J. Krutmeyer DRAWN " TRACED C.A. Wigholm DATE Sept 13, 1912 SCALE	CAPACITY AND AREA CURVES SAN ANTONIO RESERVOIR SPRING VALLEY WATER CO. ALAMEDA SYSTEM			SUPERSEDES SUPERSEDED BY

WATER WILL BE STORED IN CLOSE PROXIMITY TO THE SUNOL GRAVELS.

Plate 13



MAP & SECTION OF DAM OF SAN ANTONIO RESERVOIR

reservoir occurred four times, one of which was large and the other three small. The surplus waters are as follows:

Season.	Amount, M. G.
1892-93	900
1893-94	1,100
1894-95	2,800
1896-97	300
Total	5,100

The reservoir was just empty at the beginning of the floods of 1905-6, at which time the storage increased rapidly in spite of the draft upon it, and was practically full at the end of the floods of 1910-11.

The gross draft from the San Antonio Reservoir under these conditions is found to be 10.95 M. G. D.

By deducting an evaporation loss of 48″ per year over the area of the water surface of the reservoir the net safe yield becomes 8.92 M. G. D.

Surplus Water From San Antonio Reservoir Enters Sunol Gravels.

The surplus waters in the seasons above enumerated will be discharged into the Sunol Gravel Reservoir, where they will assist in maintaining the draft from the Sunol gravels.

The San Antonio Reservoir and the Sunol Gravel Reservoir are so closely related that they will always be operated in unison, San Antonio Reservoir being, in fact, a regulator. Effort will be made to keep the water in the gravels rather than in the surface storage reservoir in order to reduce loss of evaporation. For, whereas in a storage reservoir the surface of the water is subject to the action of the direct ray of the sun as well as thirsty winds, in the gravels the water is covered and cool, and capillary tubes, which form like so many myriads of pumps in the denser soils and thereby pull the water to the surface to be evaporated, do not form in gravel and sand, such as make up the great body of gravel at Sunol. Fortunately these gravels are for the most part uncovered with soil, and where soil does exist it is a thin layer.

Thus it is seen that probably both the efficiency and productiveness of the San Antonio Reservoir will be increased by its use in harmony and conjunction with the Sunol gravel reservoir.

Plate 12 shows the storage capacity and area of water surface for different depths in the San Antonio Reservoir.

Plate 13 shows a topographical map of San Antonio Reservoir and section of dam.

The Arroyo Valle Reservoir Is Located a Short Distance from Livermore Valley.

The Arroyo Valle Reservoir is located in the Arroyo Valle Creek, about 7 miles from the town of Livermore. It is 4 miles upstream from the Cresta Blanca Winery and Vineyard, where the Arroyo Valle debouches from the hills and begins to sink into the great gravel reservoir underlying Livermore Valley. It is a rather long, narrow valley, about 3 miles long and about one wide in the widest place, surrounded on all sides by rugged mountains.

Catchment Area.

Above the site of the Arroyo Valle Reservoir there is a tributary catchment area of 140.8 square miles, striking in a general southeasterly direction past the eastern flank of Mt. Hamilton to the headwaters of the Coyote River.

Exposed rocky slopes are to be observed very generally throughout the watershed, some of the most inaccessible parts of the Alameda System lying within its limits. Personal examination of this catchment area shows it to be one of fairly good rainfall, favorable to high run-off, though not equal to the productiveness of the Calaveras watershed.

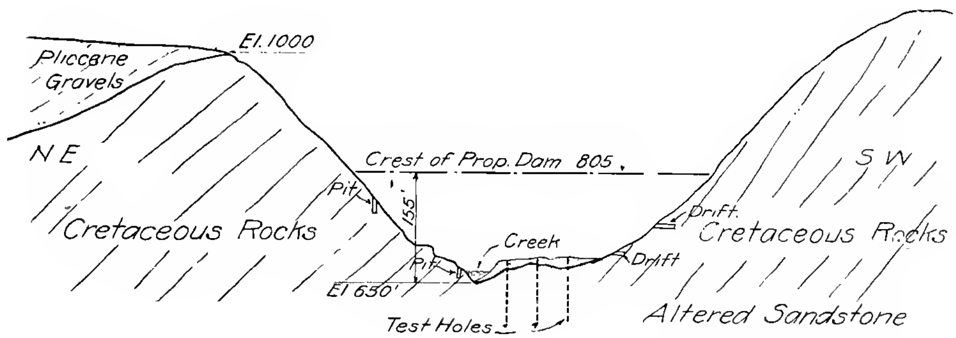
Precipitation.

Precipitation occurs both in the form of rain and snow. Even in the exceptionally dry winter of 1911-12, snow fell in this watershed.

No precipitation record covering long periods has been kept within the watershed, the longest being at the Arroyo Valle Reservoir site, which covers the seasons of 1904-5, 1905-6 and 1911-12. The result of two years' observations at 18 stations lying in the extreme southerly end of the watershed is given by Messrs. Haehl & Toll in Vol. 61 of the Transactions of the Am. Soc. of C. E., and previously discussed.

The longest record near to the watershed is at Livermore, lying out in the open Livermore Valley. This record covers 41 years, from the

Plate 14



N.E.-S.W Section across Arroyo del Valle
at the upper damsite looking up-stream

APPROVED BY				
BY .... DRAWN A.J.Krutmeyer TRACED ...."....... DATE Sept. 14, 1912 SCALE	GEOLOGY ARROYO DEL VALLE RESERVOIR SITE SPRING VALLEY WATER CO ALAMEDA SYSTEM			SUPERSEDES .... SUPERSEDED BY..........

GEOLOGICAL SECTION OF ARROYO VALLE DAMSITE BY DR. J. C. BRANNER.

Dr. Branner Pronounces this Damsite Excellent. Explorations Made Confirm Selection.

season of 1871-72 to the present date. The locations and means of the stations after expanding to 63 years are shown on Plate A-2 and are discaused in detail in Appendix "A". From the isohyetal lines on Plate A-2 the mean areal precipitation is found to be 20.80 inches. (Appendix "A".) During the past 23 years the minimum areal precipitation is found to be 11.20 inches per season, and the maximum 37.10 inches per season.

Actual Gagings of Arroyo Valle for Five Years.

The run-off from the Arroyo Valle catchment area is discussed in Appendix "B".

Actual run-off measurements at Arroyo Valle Reservoir are available for the period 1905-6 to 1907-8 and for the first half of the year 1912. The measurements show that the regimen of the stream varies between wide limits, the low water flow being less than 1 M. G. D., while floods in exeess of 3000 M. G. D. have been measured. Naturally, the entire low water flow sinks into the Livermore gravels, as does also perhaps half of the flood waters, the remainder escaping into Laguna Creek and eontributing to the disastrous floods below Niles, previously mentioned.

When these works are completed the floods will infliet far less damage on people living below, and the water will be put to useful purposes.

Utilizing the run-off curves developed and discussed in detail in Appendix "A". From the Arroyo Valle Catchment area has been estimated approximately for the period 1849-50 to 1888-89, and with greater accuracy for the 23-year period, 1889-90 to 1911-12, where we have complete record of discharge measurements for the whole Alameda System, and numerous other discharge measurements for the subsidiary catchment areas. Where actual measurements are available they are, of course, used.

Arroyo Valle Dam Has Excellent Foundations.

Plans for the Arroyo Valle Dam call for an earthern structure 155 feet high. The site is a very good one. as indicated both by geological examination and by exploration work. The exploration works consist of both shafts and drill holes. Plate 14 shows the geological formation as determined by Dr. Branner. The results of exploration are shown on same plate.

The height of this dam is limited to 155 feet, not because of any foundational conditions, but because this is believed to be amply high to conserve all the waters of the Arroyo Valle when used in conjunction with the Livermore gravels. Should it be warranted by longer records and experience, this dam. like that at San Antonio, may be increased in height to the practical limit of that type of structure.

Ample amounts of excellent dam material are available very close to the site.

Storage.

The Arroyo Valle Reservoir as designed, with a height of 155 feet, will have a storage capacity of 13,830 M. G. By increasing the height to 195 feet, 20,000 M. G. storage would be made available.

Arroyo Valle Reservoir Will Regulate Floods and Conserve all Water.

The Arroyo Valle Reservoir, because of its strategic position with regard to the Livermore underground gravel reservoir, may be used in two ways, either as a purely storage reservoir, or as a regulating reservoir, in which latter capacity it will serve very materially to increase the amount of Arroyo Valle water which will be absorbed by the Livermore gravels. This great advantage will appeal to anyone versed in the operation of water supplies.

If used purely as a storage reservoir, effort would be made to keep the reservoir full, regardless of the size, occurrence, or character of floods, and much waste and loss by evaporation would result.

On the other hand, if used as a regulating reservoir, effort would be made to keep it empty. By this I mean, that its office would be to retard the floods, letting the water down into the underground gravel reservoir as rapidly as the gravels could be made to absorb it, and thereby providing an empty reservoir to smooth out the flood wave of the next flood. These floods are of very short duration and extremely high intensity, and without such regulation would rush out over the gravel too rapidly to be completely absorbed.

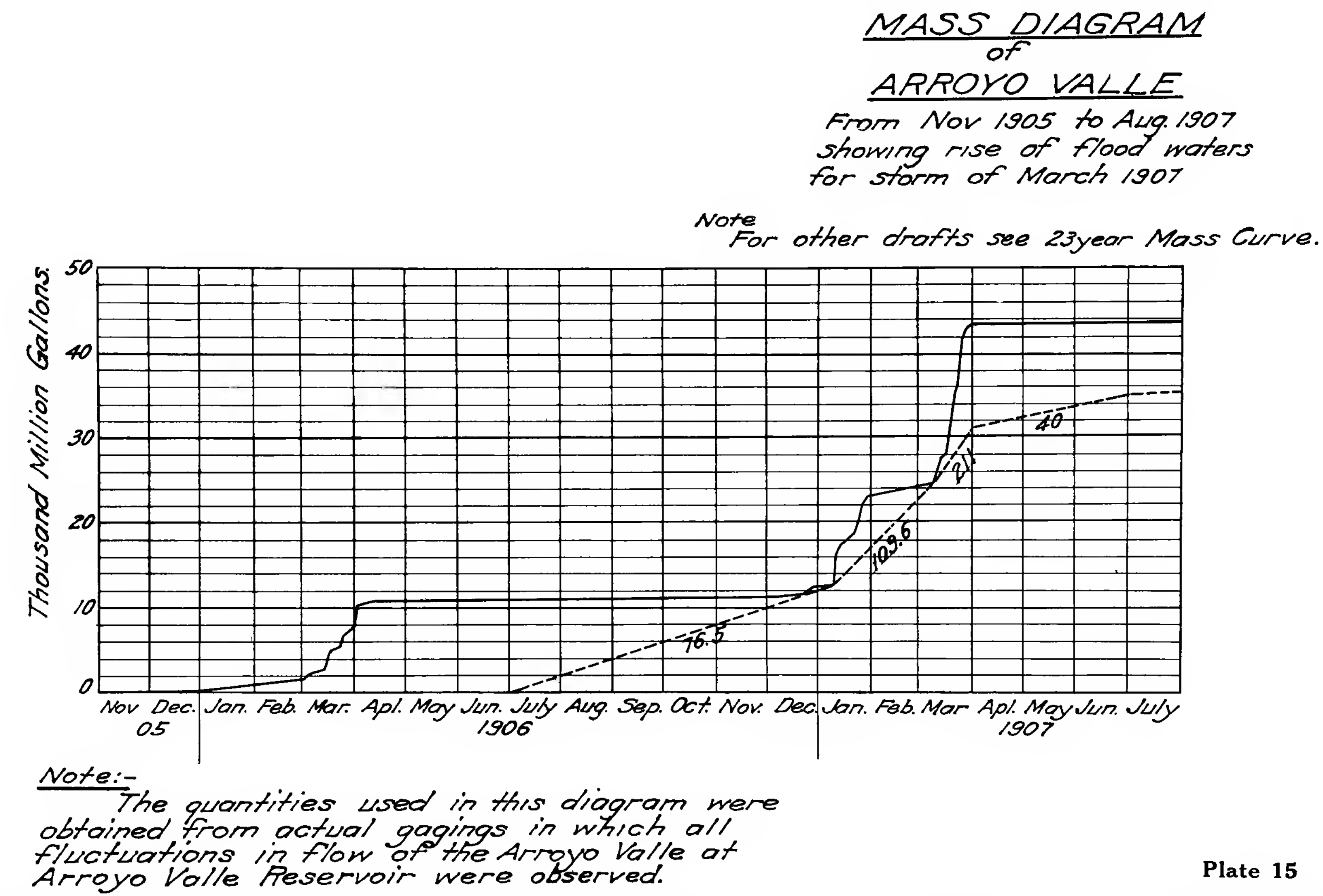
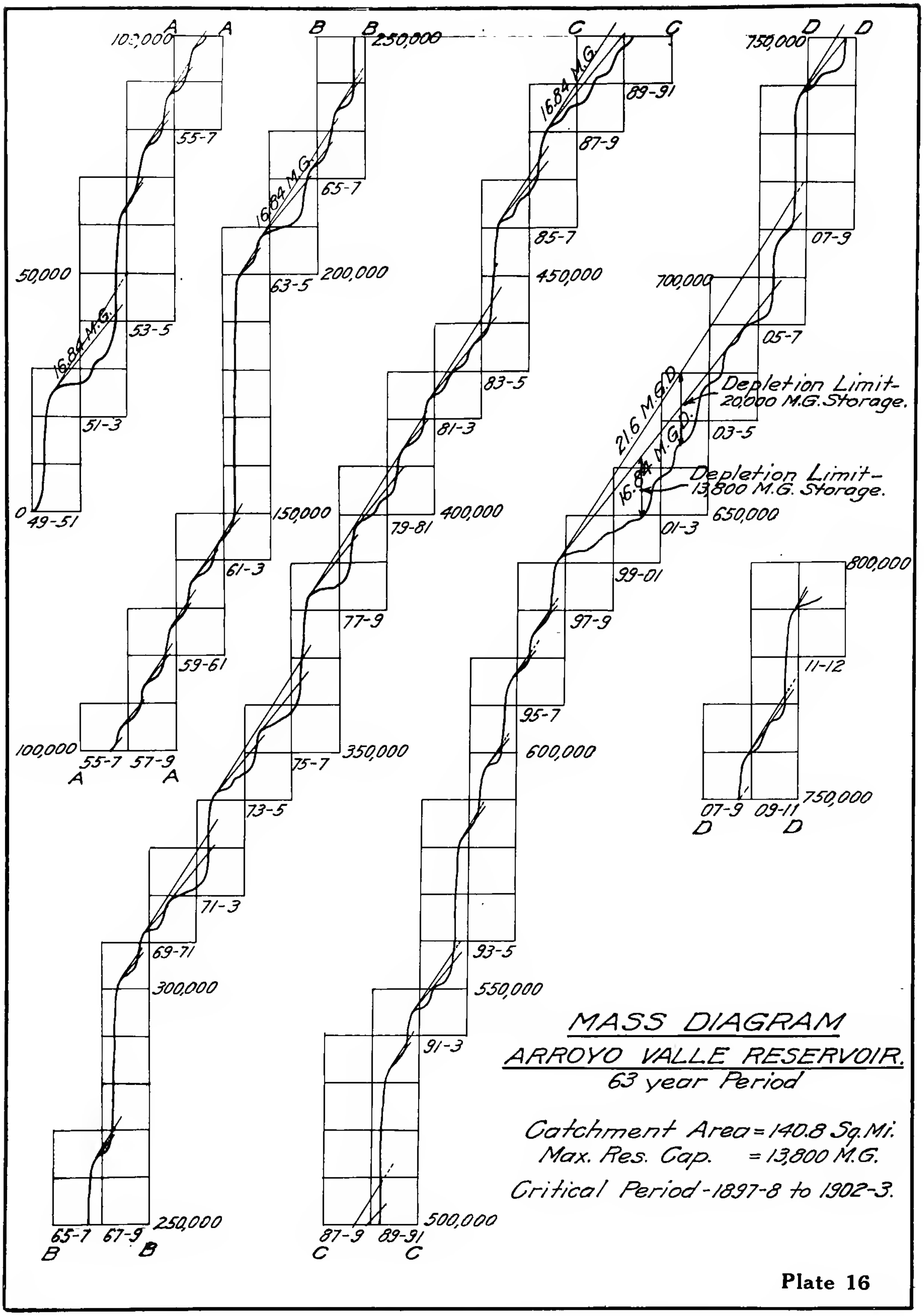


Plate 15

SHOWING FROM ACTUAL GAGINGS IN ONE OF THE LARGEST FLOODS OF THE ALAMEDA SYSTEM, HOW THE ARROYO VALLE WILL SERVE AS A REGULATOR, DELIVERING WATER AT A RATE SUSCEPTIBLE OF EASILY SATURATING THE LIVERMORE GRAVELS.



ARROYO VALLE RESERVOIR WILL BE MORE EFFICIENT AS A REGULATOR THAN AS A PURELY STORAGE RESERVOIR.

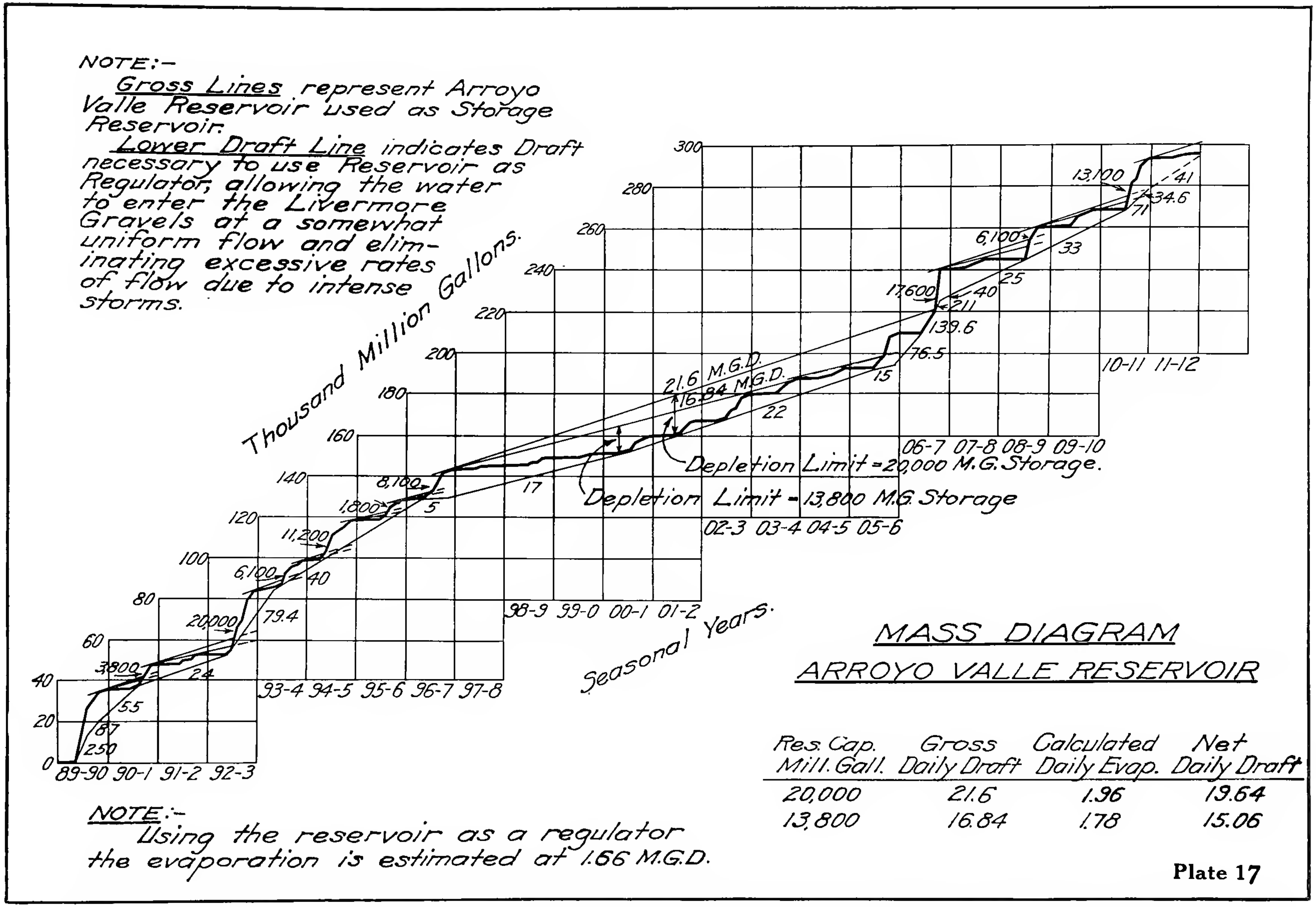


Plate 17

IF ARROYO VALLE RESERVOIR WERE TO BE USED SOLELY FOR STORAGE INSTEAD OF AS A REGULATOR, IT WOULD BE BUILT TO HAVE 20,000 MILLION GALLONS STORAGE, AND WOULD YIELD OVER 21 MILLION GALLONS DAILY.

Taking the seasons 1905-06 and 1906-07 as an example, where we have actual measurements of the stream flow at Arroyo Valle, the peak of the high flood in this case, which occurred March 23, 1907, was at the rate of over 3000 M. G. D. These seasons have been plotted in the form of a mass diagram on Plate 15, which shows the rapid jumps in the flow during storms. By using the reservoir as a regulator and letting the water out at the rate of 211 M. G. D., the reservoir would never have been more than full. Thus, instead of an abrupt and intense flood of 3000 M. G. D. reaching the surface of the underground gravel reservoir, water would be applied to the gravel at a rate not to exceed 211 M. G. D., which is a very convenient amount of water to handle.

Similarly, for the flood of March, 1906, instead of contending with a flood at the rate of nearly 2500 M. G. D., by using the Arroyo Valle Reservoir as a regulator, even less than 211 M. G. D would have to be applied to the gravels. It will be noted that in this way the water handled is at the rate of less than 10% of the flood rate, showing the great efficiency of the Arroyo Valle Reservoir in arresting the floods from its catchment area.

Observations made on the gravels in the creek bed of the Arroyo Valle Creek showed that water entered them freely at the rate of 10 cubic feet per square foot per day, or approximately 180 M. G. D. per square mile of superficial area, and this in the winter of 1911-12, when the entire flow of the Arroyo Valle sank into the Livermore gravels. I have analyzed the Arroyo Valle Reservoir in both ways.

Plate 16 shows a mass curve of flow at Arroyo Valle Reservoir as estimated for 63 years and Plate 17 shows the mass curve for Arroyo Valle Reservoir for the flow for 23 years, as determined in Appendix "B". On this latter plate is also shown the gross safe draft from Arroyo Valle Reservoir if considered purely as a storage reservoir, which is nearly 17 M. G. D., *with many waste periods.*

If used as a purely storage reservoir, the height of the dam would be increased about 40 feet, giving a storage of 20,000 M. G. In this case the gross safe draft would be 21.6 M. G. D., with the following waste:

Season	M. G.
1890-91	3,800
1892-93	20,000
1893-94	6,100
1894-95	11,200
1895-96	1,800
1896-97	8,100
1906-07	17,600
1908-09	6,100
1910-11	13,600
Total	88,300

It is seen from Plate 17 that the period 1897-98 to 1905-6 determines the safe draft.

Regulation by Arroyo Valle Reservoir Simplifies Handling of Floods.

Considering the Arroyo Valle Reservoir now as a regulator with a storage of 13,830 M. G., we find (Plate 17) that without more than filling the reservoir at any time the maximum draft that will be required is at the rate of about 250 M. G. D. in 1889-90. The next greatest draft is 211 M. G. D. in 1906-7, all the others being less than 100 M. G. D.

These drafts represent the rate at which water must be applied to the surface of the underground reservoir from the Arroyo Valle Watershed. Unless they occur when the gravels are in a state of complete saturation, it is a simple matter to force the gravels to absorb water at these rates. It is very common for irrigation projects to handle more than this amount and to force it into the ground.

In the Imperial Valley, in Southern California, many times this amount of water has been handled and forced into the minute pores of the dense clayey soils, instead of such surface as the open, porous gravels of the Livermore Valley. The Colorado River water used in Imperial Valley probably deposits more silt in a single irrigation than would the whole of the flow from the Arroyo Valle Watershed in a century.

Arroyo Valle-San Antonio Tunnel.

The Arroyo Valle Reservoir may be connected with San Antonio Reservoir by means of a tunnel four miles long, whereby, if it is found desirable, the waters stored in the Arroyo Valle Reservoir may be discharged into the San Antonio Reservoir, where they may be held temporarily,

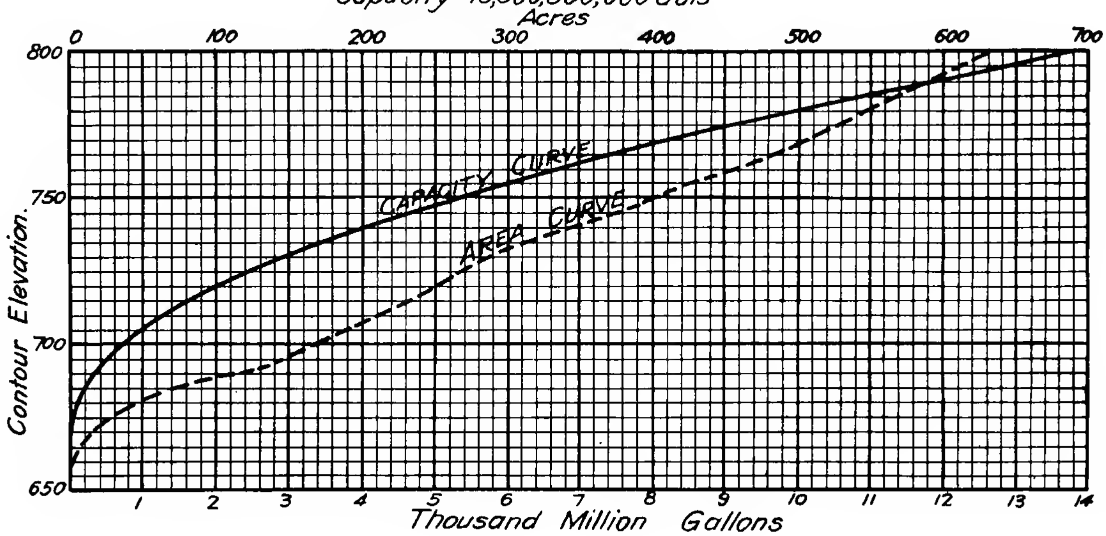
Plate 18

ARROYO VALLE RESERVOIR

Capacity and Area

Contour Elevation	Area in Acres	Capacity in M.G.
650	0.00	0.0
660	1.98	3.0
670	12.89	27.4
680	39.37	112.4
690	109.00	364.0
700	166.00	792.0
710	207.00	1380.0
720	248.00	2110.0
730	285.00	3085.0
740	346.00	4050.0
750	400.00	5290.0
760	457.00	6690.0
770	506.00	8310.0
780	547.00	10040.0
790	585.00	11910.0
800	630.00	13830.0

Crest of Dam Elev 800'
Max. Water Height Elev 795
Capacity - 13,800,000,000 Gals



Calculations from Map F-50

Crystal Springs Datum

APPROVED BY				
BY. A.J. Krutmeyer. DRAWN A.J. Krutmeyer. TRACED C.A. Wigholm DATE Sept. 12, 1912 SCALE	CAPACITY AND AREA CURVES ARROYO VALLE RESERVOIR SPRING VALLEY WATER CO. ALAMEDA SYSTEM			SUPERSEDES SUPERSEDED BY

WILL BE USED TO REGULATE LARGE FLOOD IN THE ARROYO VALLE. WITHDRAWALS WILL BE MADE IN CONVENIENT AMOUNTS TO SATURATE LIVERMORE GRAVELS.

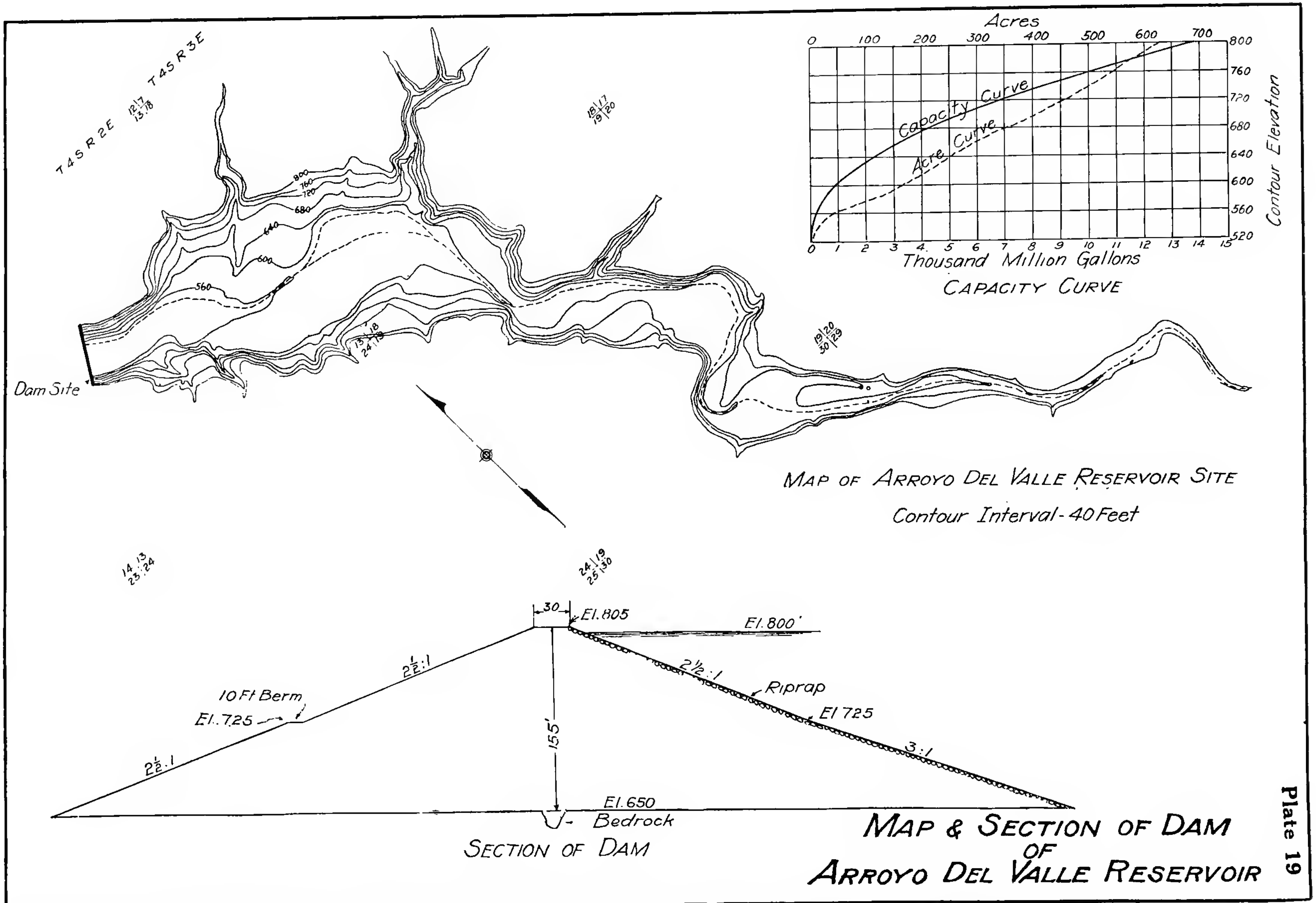


Plate 19

MAP & SECTION OF DAM OF ARROYO DEL VALLE RESERVOIR

THIS LARGE RESERVOIR SO SITUATED AS TO AFFORD REGULATION OF THE FLOOD WATERS OF THE ARROYO VALLE AND INSURE A YIELD OF 55 MILLION GALLONS DAILY FROM THE LIVERMORE GRAVELS.

or whence they may be conveyed to San Francisco.

Because of the fact that the Arroyo Valle Reservoir is 350 feet higher than the San Antonio Reservoir, *power* may be developed by this water.

Plate 18 shows the storage capacity and area of water surface for different depths in the Arroyo Valle Reservoir.

Plate 19 shows a topographical map of the Arroyo Valle Reservoir and a section of the dam.

Livermore Underground Reservoir.

The Livermore Valley comprises an area of about 60 square miles, lying in the easterly portion of Alameda County, California, at an elevation of between 350 and 600 feet. It is quite flat in topography, having a gentle slope from its easterly to its westerly edge, a distance of 13 to 14 miles.

The floor of the valley is traversed by frequent depressions, marking the meanderings of the old stream channels as they swung back and forth in their pendulum-like motion, forming the valley fill. The valley is surrounded by foothills of varying character. Those to the west and north are quite steep and precipitous, while those to the east and south have more gentle slopes. A narrow range of hills on the east separates the Livermore Valley from the San Joaquin, while the hills to the north and south are undulating foothills to more extensive ranges. On the west the mountains rise abruptly from the plain forming the great scarp that designates the location of the San Ramon-Calaveras fault.

Up to within the last few years the western or lower end of this valley was one vast marsh and shallow lake, embracing between three and five square miles, with an abundance of such vegetation as is indigenous to soils in marshy conditions.

During the entire year water from this marsh spilled over its boundaries into Laguna Creek, which carried it seaward through Alameda Creek and Niles Canyon.

During flood stages the surface streams of Livermore Valley flowed through this marsh and lake as they wasted into San Francisco Bay, and, because of the ease with which these waters could reach Laguna Creek, but little of them remained behind.

Artesian Waters Supply Loss from Marsh Land.

The loss from evaporation from this broad sheet of marsh lands and lake was constantly replaced, and the elevation of the water surface therein was maintained from subterranean sources under stress of artesian conditions.

It has long been known by interested and observing persons that the waters which entered this marsh from subterranean sources were the reappearance of waters from the surrounding watershed. These waters sank into the porous floor of the valley during the wet season, and, in point of fact, the lake and marsh were but the spillway of an underground lake of large proportions. The availability of a large water supply from this source has long been recognized by the management of the Spring Valley Water Company, and steps were taken to acquire property and rights which would enable this Company to avail itself of the abundant water which was here annually going to waste in the form of surface run-off, evaporation and transpiration, and to utilize the great storage basin which was excavated and hemmed in by Nature.

Tributary Streams.

The Livermore Valley is the final catchment of the water product of some 400 square miles of watershed. Besides several streams of less importance, three main streams enter it from the east and southeast.

The Arroyo Valle Is the First.

Of these three, the Arroyo Valle is the largest, serving about 140.8 square miles of watershed. This stream rises in the high Mt. Hamilton range and traverses a territory whose precipitation ranges from 7 to 37 inches per year, and whose topography and geology are favorable to good run-off. It enters the valley on the south side at a point about three-quarters the distance from its westerly to its easterly extremity and nearly due south of the town of Livermore. After entering the valley the creek flows northeast, along a very wide and shallow channel, near to and parallel with the foothills which form the southern boundary of the Livermore Valley. All along the course of this channel are seen depressions and benches which indicate the direction

TYPICAL GRAVELS OF LIVERMORE VALLEY.
With Arroyo Valle Reservoir these Gravels Will Support a Draft of Over 55 Million Gallons Daily.

the stream followed in the past as it wandered through the valley. All of these branches and depressions are made up to a large extent of gravels and sands, which are now hidden, with only a small amount of gravelly soil. The Arroyo Valle continues in a northeasterly direction for some six miles, until near the town of Pleasanton it swings to the west and continues on through Pleasanton to Laguna Creek, having traversed the valley in its meanderings for a distance of over nine miles.

Just a short distance from the point where the stream turns to the west, it leaves the wide gravelly beds through which it has been passing and enters a more restricted channel, the banks of which are a fine, silty, sandy loam. This fine sandy soil continues to Laguna Creek.

The Arroyo Mocho Is the Second.

The Arroyo Mocho is the second largest creek entering Livermore Valley. It lies to the east of the Arroyo Valle and drains from the south in a general northwesterly direction, paralleling the Arroyo Valle and serving a watershed of about 46½ square miles. It enters the Livermore Valley near the southeast corner about five miles southeast of the town of Livermore, and continues in a northwesterly direction across the valley floor, passing just to the south of Livermore. Upon entering the valley the Mocho follows a very wide, flat, gravelly channel, with wider gravelly overflow plains on either side. The width of this overflow plain increases as the stream approaches Livermore, where the banks are so low that it has been known to overflow and force great streams of water over the streets of the town, more than a mile away from the main channel. About one mile below Livermore the main stream channel runs through a fine, sandy loam. As the stream emerges from this loam soil, about two miles west of Livermore, its waters spread out over the broad floor of the valley, and when the ground is not already completely saturated they disappear.

Of recent years the owners of the lands subject to this inundation have endeavored to prevent the waters from spreading broadcast by constructing an artificial canal westerly, and at the present time it may be said that there is a well-defined artificial channel to a point within three miles of Santa Rita. Beyond this point, however, there is no distinguishable channel, even at this time, proving conclusively that the waters sink into the gravels.

The building of the canal to carry the Mocho waters throws much light upon the character of the material over which these waters naturally spread and into which they have always disappeared. For the entire distance along this canal the levees are made up almost entirely of gravel and coarse sand, there being very little soil of any kind. Applying the same conditions to the large area over which the flood waters spread, one can readily understand why the Mocho waters so rarely escape to Laguna Creek.

The Arroyo Las Positas Is the Third.

The creek of third importance is the Arroyo Las Positas. This creek drains a low altitude watershed to the northeast, as well as the eastern portion of the Livermore Valley, comprising in all 81.7 square miles. The run-off from this watershed enters the main portion of the valley just north of Livermore, where the low hills separate the main Livermore Valley from Cayetano Creek to the north. The Cayetano joins the Arroyo Las Positas as it emerges from the hills and runs in a westerly direction, this joint stream gradually bearing away from the northerly edge of the valley and originally continuing until their waters joined those of the Mocho overflow about one mile southeast of Santa Rita.

The soil and general topography of the country indicate beyond doubt that the water of the Arroyo Las Positas, during times of flood, overflowed its banks and spread out to the south, joining the flood waters of the Mocho that spread over the porous gravelly area west of Livermore. Of late years the Arroyo Las Positas has been confined within its banks by a system of levees, which extends from Laguna Creek for many miles along its course towards the point where it enters the valley. Unlike the Arroyo Valle and the Arroyo Mocho, the Arroyo Las Positas at no place along its course traverses any extensive exposed beds of sand or gravel, but, on the contrary, all of its course lies in clayey adobe and clay loam. In fact, with as small a discharge as four or five second feet at the point where it enters the main Livermore Valley, it will de-

crease only a small amount between there and the point where it joins the artesian waters just east of Santa Rita.

Diablo Drainage Feeds from the North.

Sixty-nine square miles of watershed, lying just north of the Livermore Valley are served by Collier, Cottonwood, Tassajero and Alamo Creeks. The first three of these emerge from the hills and continue in a general southerly direction, discharging their waters into the Arroyo Las Positas. The Alamo Creek is the most westerly of this group. It drains a watershed of about 26 square miles and enters the valley near its northwestern corner. It runs in a southwesterly direction, cutting across Amador Valley and joins Laguna Creek just east of the town of Dublin.

All the streams entering the valley from the north traverse beds of clay adobe soil and only in limited areas do their courses show soils of sandy nature. None of the streams from the northern side of the valley are afforded opportunity to enter the soils because these soils are constantly in a state of saturation from the artesian waters that are forced up from the gravels beneath.

Arroyo de la Laguna Carries Away Waste Waters.

The water, leaving Livermore Valley by surface channels, does so through Arroyo de la Laguna. This creek rises in the Amador Valley, the extreme northwestern braneh of the Livermore Basin. It follows in a general southerly direction at the base of the steep Pleasanton range of hills and prominent fault scarp previously mentioned, which form the western boundary of the Livermore Valley. Upon leaving the valley it continues down a gorge of varying width, until it joins Alameda Creek near Sunol, the water of the two continuing toward the sea by way of Niles Canyon. The Laguna Creek, in passing through the Livermore Valley, traverses for a considerable distance a sticky clay adobe soil, after which it runs through various mixtures of fine, silty, sandy and clay loam, and not until it enters the canyon does its bed contain gravels to any extent.

Dr. Branner Studies Geology of Valley.

A most comprehensive discussion of the Livermore Valley in regard to its geological formation and adaptability as an underground reservoir is to be found in a report of May 6, 1912, by Dr. J. C. Branner, Professor of Geology and Vice-President of Stanford University, one of the foremost geologists in the world, and who is now preparing a geological monograph of the very complex geology of this region for the United States Geological Survey.

I have spent weeks in the field, either with Dr. Branner or his assistants, and know that most careful and painstaking measurements and investigations were made to determine the true history of this most complex geology. He and his men have worked early and late with indomitable energy.

With great interest I have watched this master mind pick up the tangled threads of field observations and weave them into a perfect fabric. His long experience in work on the underground waters around San Francisco Bay was of invaluable aid to him in this instance.

In view of this most enlightening report it might seem superfluous for me to more than reiterate those salient features which more especially bear on my quantitative deductions.

Dr. Branner Finds Enormous Depth of Gravel.

Dr. Branner finds two distinct sets of gravels underlying the Livermore Valley:

1. *The Pliocene Gravels.* The hills south and southeast of Pleasanton, and south and southeast of Livermore, in fact, all the hills directly adjacent to and forming the southern boundary of the Livermore Valley are composed of extensive Pliocene deposits of interbedded lenticular kidneys and beds of gravels, sands and clays, many of the beds being of a very coarse and porous nature. Dr. Branner finds that these deposits are of fresh water origin and dip quite uniformly toward and under the Livermore Valley at an angle of from 20° to 23° The total thickness of these deposits he finds to be the enormous depth of 4000 feet, with an exposed area of 47 square miles.

These Pliocene deposits extend from the ex-

treme western edge of the valley to the extreme eastern edge, and from the hills on the south to a line near the northern edge of the valley, extending through Dublin and the north edge of the town of Livermore. To the north of this latter line the geological formation underlying the valley fill is much older, there having been a great uplift in which the beds of the Pliocene gravels and clays were raised to an elevation much higher than the present valley fill. The upper part of this uplift has been eroded away and a large part of the present valley fill represents the coarser residue of this erosion.

A similar uplift has taken place along the western edge of the valley, shutting off all possibility of the underground waters escaping in that direction. Thus Nature has provided a cup of gigantic dimensions, filled with porous material, creating this enormous underground lake.

The Pliocene gravels vary greatly in character, being open water-bearing sands and gravels in some places, and compact, clayey beds in others. When long exposed to weathering and oxidation they often take on the appearance of being quite impervious, while deeper down and well under cover, where the weather cannot affect them, these same beds are quite open and full of water.

The knowledge of the oecurrence of the Pliocene gravels in the region of San Francisco Bay is by no means new. Those near Pleasanton are portions of the same beds of gravels that underly the northerly portion of Santa Clara Valley and some of the margin around San Francisco Bay. They are exposed on the foothills along the western slope of Santa Clara Valley, and, like the exposed portions of the Pliocene gravels near Livermore Valley, they appear impervious. Yet these are the selfsame gravels that are tapped by the deeper wells of Santa Clara Valley that yield an unfailing and abundant supply of water from a depth of from 700 to 1000 feet below the surface of the ground.

Pliocene Gravels Are Found to be Rich in Water.

I have examined these exposed beds of Pliocene gravels of Santa Clara Valley, in company with Dr. Branner, and have been amazed at how easily one not familiar with them may be deceived into believing them impervious.

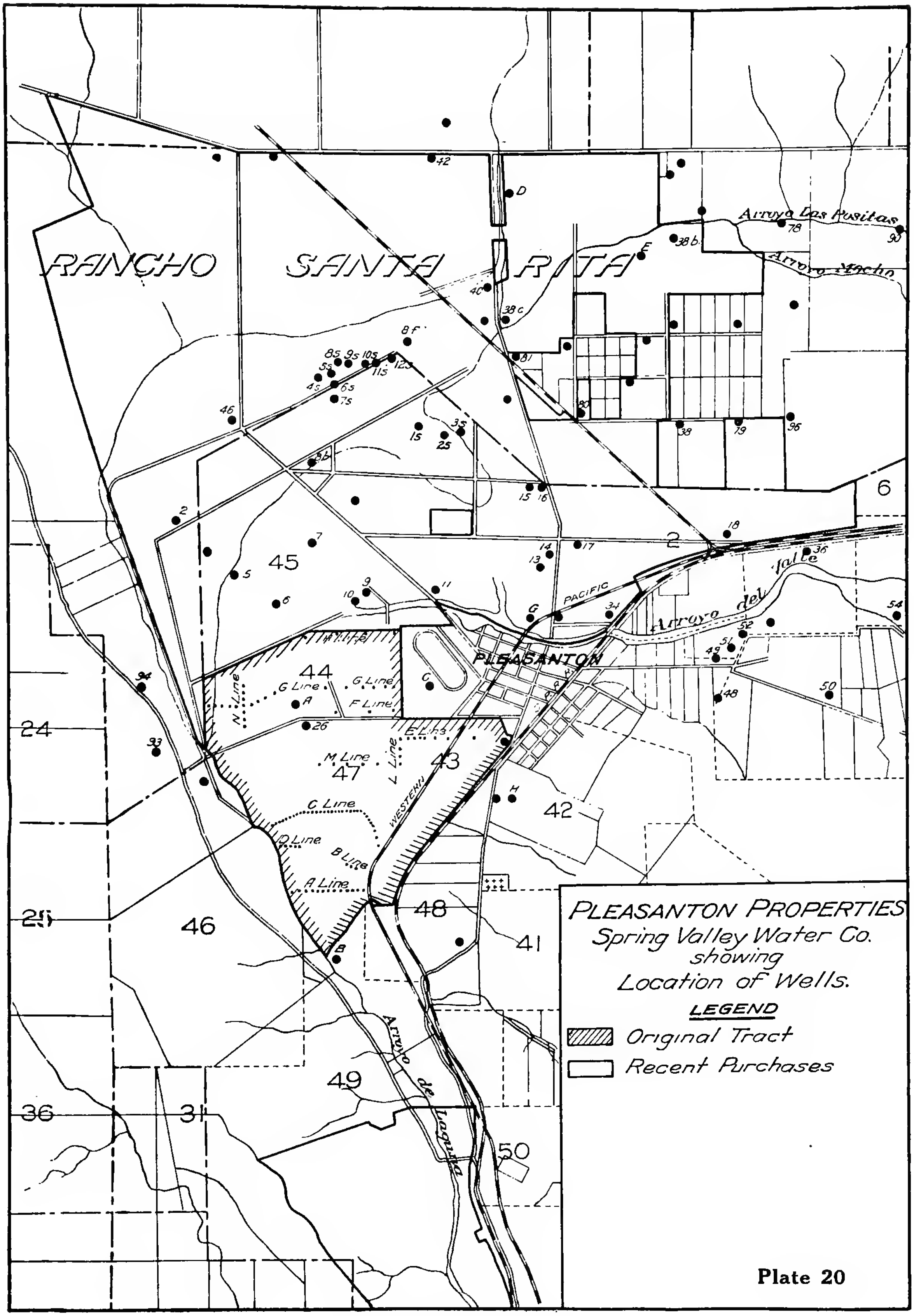
The sources of subterranean water around San Francisco Bay are fruitful fields for gelogical study and investigation, and Dr. Branner has covered this field thoroughly for many years. Through many years of work with and intimate knowledge of the subterranean waters of Santa Clara Valley, I am very familiar with the copiousness of their supply. Statements, therefore, that stamp the Pliocene gravels as impervious are based on either superficial knowledge or prejudice.

The absurdity of relying upon the apparent surface imperviousness is well illustrated by the artificial lake recently constructed in the Pliocene beds at Stanford University. In discussing this, Dr. Branner says that the outcrop showed:

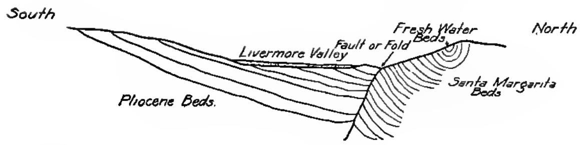
> "close compact Pliocene beds, but when the excavation was carried on some twenty-five feet or more into the formation, and water was turned into the basin, the water escaped underground and caused a marked rise in the water level in wells about Menlo Park, 2 miles away."

Dr. Branner further states that the saturated surfaee condition along the north side of the Livermore Valley that prevents the waters of the Arroyo Las Positas and streams from the north from sinking is eaused by artesian waters from the Piocene gravels rising along the fault line and forcing their way through the overlying denser materials.

> "It is now evident that the Pliocene beds that have a thickness of more than 4000 feet in the hills south of Pleasanton, as pointed out in my former report, dip northward at an angle varying from ten to twenty-five degrees, and pass far below the valley floor. The rocks forming the south face of the hills on the north side of the valley belong to an older series, and the Pliocene beds cannot therefore pass beneath them, but must either bend very abruptly upward, or they must have been let down by a fault against the older beds. In either case the waters that enter the Pliocene gravels in the region south of the valley must follow down along their bedding planes and rise to the surface along the north side of the valley where the fault or the upturned beds allow them to escape.
>
> "The accompanying figure, representing a north-south section across the valleys, will make my meaning clear:"



LOCATION OF WELLS.



That the Pliocene gravels are water-bearing and even artesian is further illustrated by several artesian wells above the valley floor in the Pliocene gravels south and southeast of Pleasanton.

Upper Gravels Have Great Wealth of Water.

2. *Alluvium Valley Fill.* Dr. Branner finds that widespread alluvial deposits of gravels, sands and clays have been gradually deposited over these Pliocene gravels as the great uplift along the Calaveras fault line proceeded. These materials vary greatly in thickness and alternate with each other irregularly, and, as they form the upper water-bearing strata from which water is now being withdrawn and which it is proposed further to develop, they are of especial interest and importance.

The uplift west of the Calaveras fault line is the accumulated displacement of untold centuries, as Nature worked inch by inch in remodeling the topography of this region. Years have no place in accounting the time occupied in this change, the formation of the gravels probably going back to the glacial period. Because of this, these alluvial gravels were deposited by run-off, whose quantity and velocity were very much greater than at the present time. Therefore to a great extent they must be very coarse and porous. The stream of the present age has, however, carried down light material and formed a blanket, as it were, over the older deposits, so that an inspection of the surface conditions does not readily indicate the great extent to which the valley fill is composed of coarse material, and it is only by an examination of the logs of wells that this is brought out.

Dr. Branner Studies Records of 200 Wells.

In studying the geology of Livermore Valley Dr. Branner and his assistants interviewed the residents of the valley and collected the logs of over one hundred wells widely distributed over the valley, the location of which are shown on Plate 20. He found that only very rarely had inhabitants kept accurate record of the material penetrated in boring. But he was able to obtain considerable data of the more recent borings from logs kept by the well borers themselves.

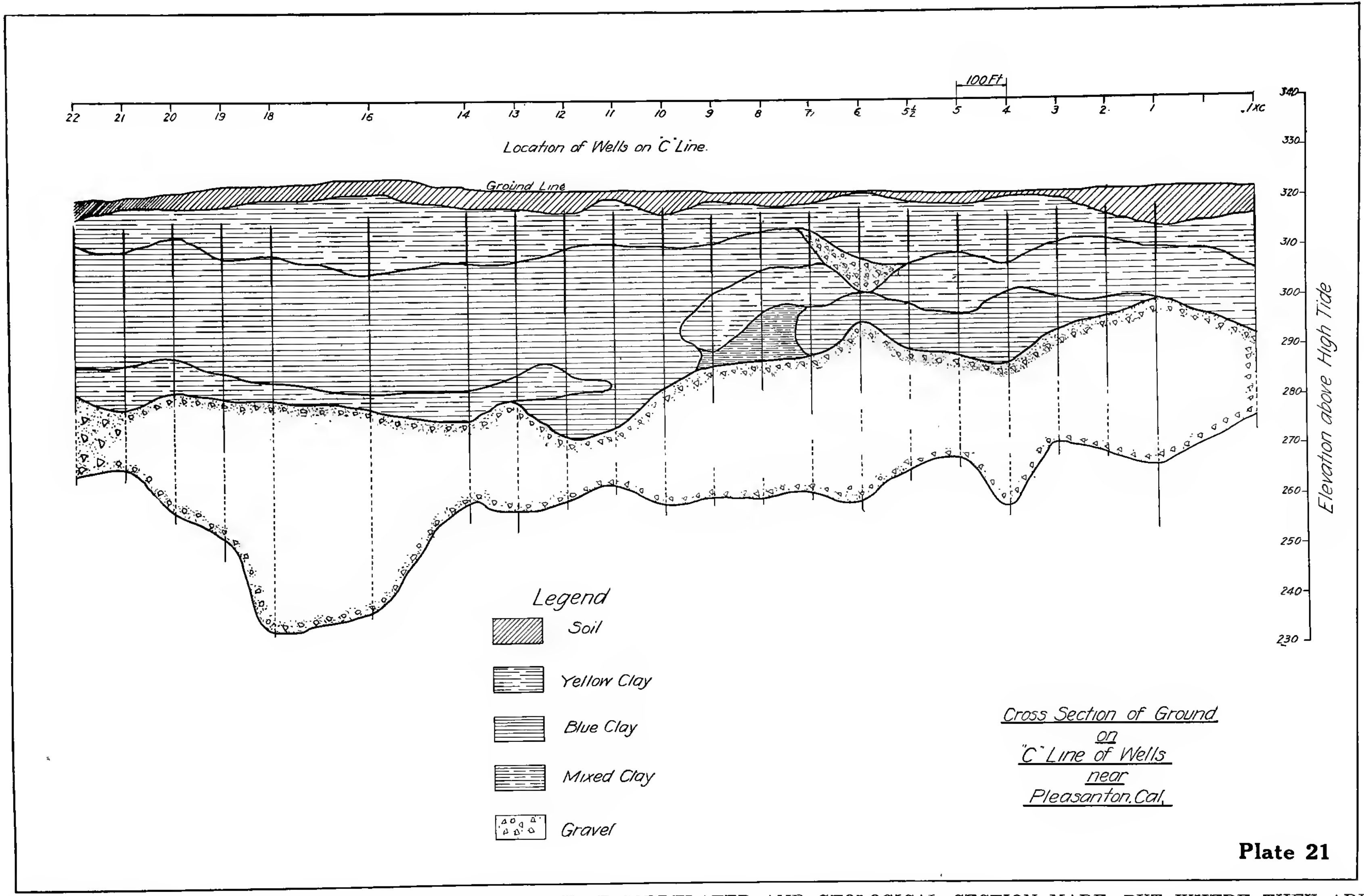
He found that, while the well borers of Livermore Valley were doubtless very practical and efficient in the art of well boring, their records were very crude, and the actual notes seemed in in many instances to conflict with the recorders' interpretation of them.

However, Dr. Branner collected enough reliable information to convince him that the upper valley deposits were no different in general character from the deposits west and southwest of Pleasanton, which the Spring Valley Water Company had extensively explored by well borings.

These wells were put down in a tract of about 1000 acres, at the throat or lower end of Livermore Valley, acquired by the S. V. W. Co., beginning in August, 1898. This work was in harmony with the general policy of the Company to acquire and begin to develop water resources far in advance of actual needs, with the end in view that ample water would always be available to the people of San Francisco. With marvelous foresight Mr. Hermann Schussler realized the great value of this project and demonstrated it by sinking these wells.

More than one hundred wells have been bored on the Spring Valley Water Company's 1000 acres, the records of all wells being kept with much care and under the direction of trained engineers, so that their logs are by far the most reliable record obtainable of the general underground structure. It was after a careful study of these logs, together with the logs of wells collected by Dr. Branner (making in all the logs of over 200 wells), that Dr. Branner most emphatically reiterated and confirmed his preliminary statements as to the Livermore Valley fill being irregular lenticular deposits, more or less indirectly connected and laid down by abundant waters of shifting streams of the glacial period and since. The logs of all the wells considered are to be found in Appendix "E".

The wells in the property of the Spring Valley Water Company's 1000-acre tract are arranged in lines and close enough together along



WHERE WELLS ARE CLOSE TOGETHER THEIR LOGS MAY BE CORRELATED AND GEOLOGICAL SECTION MADE, BUT WHERE THEY ARE FAR APART THIS IS IMPOSSIBLE.

the lines (rarely more than 100 feet apart), that one may trace the lines of demarcation between gravels and denser materials *along the lines of the wells,* as shown on Plate 21.

Wells Too Far Apart to Draw Geological Sections Across Valley.

The lines of the wells, however, are too far apart to correlate and determine the distribution of gravels and clays between them. This must of necessity be true because of the manner in which they were laid down.

The wells not within this 1000 acres are so widely scattered that even to suggest lines of contact between gravel, sands and clays between them is impossible; lines which Dr. Branner says "a professional geologist would not venture to draw."

A study of the logs of these Spring Valley Water Company's wells, especially when plotted and placed side by side, materially aids in realizing the magniture of the underground reservoir in the upper gravels and in this way one's superficial observations as to the impervious character of these deposits is most quickly corrected.

The logs of wells outside the 1000-acre tract, when used in conjunction with other geological data and phenomena, but indicate the extent of the underground reservoir, and may be used to determine in general the proportions of the various classes of materials.

"Clay-Cap" Is Very Fine Sand or Silt.

The well logs show that as a rule over this total area the upper 35 feet of material is composed of surface soil, clays, fine sand and silt, and some gravel deposits. The surface material is relatively dense when compared with the underlying strata of very porous coarse gravels and sands. On account of its nature this first 30 or 35 feet has been termed by many a "clay cap" overlying the gravels, and it is so used in this report, at all times remembering, however, that the largest bulk of this deposit is not a true clay at all, but is in most cases a sand or a very fine silt in which decomposition of the feldspar content may have taken place.

This so-called "clay cap" covers all the area at the western end of the valley, extending from the foothills on the south to the hills on the north and from the steep western range east for a distance of about one mile east of Pleasanton.

At the eastern edge of this area the coarser material underlying the "clay cap" appears in lenticular deposits of interbedded porous gravels, and sands, and clays. These same interbedded gravels, sands, and clays continue westward under the "clay cap" and are known as the artesian gravels. The Spring Valley Water Company's wells have penetrated into these artesian gravels for an average distance of 40 feet and very little clay deposits are traversed, which are composed almost entirely of water-bearing gravels and sands. Many of the wells have been sunk to depths of over 200 feet, and they show that the clays and water-producing gravels and sands exist in about even proportion. From the well records it is impossible to state to what depths the water bearing material extends, as the deepest wells did not penetrate to the bottom of the water bearing deposits. From the general geological features, however, Dr. Branner states that it extends for over 4000 feet. Plainly, although the borings on the Spring Valley Water Company's lands show the distribution of gravel, sand, and clay near the surface, they in no way fix the extent or depth of the water bearing gravels beneath the floor of Livermore Valley.

Gravels Are Free from Silt.

From borings it is very hard to determine the detailed character of the gravel deposits, as in the process of boring much of the very fine material, if any exists, may have been washed away, and fine material from the clay strata is constantly being carried into lower strata and obviously comes from them. Because of this. the records of well borings, no matter with how much care they are taken, will not give as good a criterion of the amount of fine silt and clay as can be determined by an inspection where these gravels reach the surface and are exposed in the upper valley, as for instance the pits of the Grant Gravel Company near Pleasanton. From these pits many hundreds of thousands of tons of gravel have been excavated and still the supply appears in-

exhaustible. About two-thirds the bulk of these gravels is over ¼″ in diameter and is quite free from silts and clays. At present the gravels are being excavated by drag line scrapers, and, when possible, the bottom of the pits is kept at a lower elevation than the water table. In this way the scraper, passing backward and forward, agitates the waters so that the gravels are constantly washed, the fine particles being held in suspension. The small amount of clay is well shown when the water table in an abandoned pit falls and leaves these particles in a thin covering over the bottom of the pit. During the latter part of 1911 these abandoned pits could be seen where many hundreds of thousands of yards had been excavated and the small amount of clay washed from them formed only a very thin coating over the pit bottom.

Soils Are Sandy, Overlying Gravel.

In describing the channels of the Livermore Valley streams some mention was made of the class of soil through which they passed. The facility with which water may enter an underground reservoir has a large bearing on its practicability and value. The character of the soil through which the tributary water must enter the reservoir, therefore, bears an important part.

The U. S. Department of Agriculture's Bureau of Soils has issued a bulletin describing the soils of the Livermore Valley. This soil investigation supports the above statements as to the character of the valley fill. We are most interested in three groups of soils described in the Bulletin, classed as the Mocho, the Livermore, and the Santa Rita series.

The Mocho and Livermore groups of soils are the most important in studying the practicability of augmenting the amount of water entering the underground reservoir. These two groups comprise by far the largest percentage of the exceedingly porous surface of 24 square miles of the reservoir, and that portion which is the most susceptible to artificial saturation.

The Mocho series is the most recent, being the alluvial deposits of present and recent formations. They embrace several grades of sandy and gravelly soil, underlain in all cases by coarser material. This series of soil composes and is directly adjacent to the Mocho and Valle stream channels.

The Livermore series is made up of older alluvial and eolluvial deposits of sandy and gravelly sandy soil, and in rare cases of a clay loam. They are underlain in nearly all instances by coarser deposits of sands and gravels.

The Santa Rita series, lying in the northwestern portion of the valley, is composed of silty and clayey loams and an adobe deposited quite recently under swampy conditions. The statements of the Bulletin indicate that this class of soils is not particularly adaptable to the rapid absorption of water, though it allows of a slow percolation.

Another type not conducive to rapid absorption is the Dublin clay adobe along the north side of the valley through which the Arroyo Las Positas runs. The soil report does say, however, that the subsoil is subject to considerable variation, in cases being quite sandy, with occasional pockets of gravel.

Land-Formed Clays of Livermore Are Pervious to Water.

The formation of the Livermore Valley, and more especially the clays, must not be confused with the lacustrine or lake-formed impervious deposits, which are constantly being laid down as great blankets over the floors of lakes and large water bodies, from the light material held in suspension and brought down by tributary streams. Dr. Branner eliminated these Livermore deposits from the lacustrine type of deposits by the conditions under which they were formed and which are well explained by Messrs. Mulholland and Lippincott in their report of July 2, 1912.

Mr. Mulholland is Chief Engineer of the Los Angeles Aqueduct and Water Department. Most of his engineering career has been spent in the development of underground water supplies of Southern California. His experience in underground water has been more extensive than that of any other man in the United States, and, being a man of keen intellect and perception, he unquestionably stands without a peer in this type of development. It was he who developed over 45 M. G. D. from the underground water of San Fernando Valley, a project very similar to that of the Livermore Valley.

Mr. Lippincott is Assistant Chief Engineer of the Los Angeles Aqueduct. He has had wide experience in hydraulic engineering in the West for many years, having been in charge of the California hydrography for the United States Geological Survey, and Supervising Engineer of the United States Reclamation Service. He organized and directed the investigation of underground waters of the United States Geological Survey and has been intimately connected with a great number of the underground water developments in Southern California.

In their report they say:

> "First, as to the structural geological features of the valley, as bearing on the probability of the valley fill being largely composed of impermeable clays. It is with diffidence that we approach this subject, for the reason that you have in your possession a geological report covering the region from a most eminent authority. There are certain features, however, that are obvious even to the layman with engineering training. The fact that there has been a great down-throw of the land to the east of the Alameda ridge, or an uplift of Alameda Ridge, or possibly a combination of both of those movements, along the fault line approximately following the east base of the ridge, is evident even to the unskilled observer. That the movement was a profound one is also evident, but it does not follow and would be wholly inconsistent with all the observed occurrences of such movements, to reason that this great displacement occurred suddenly as a single cataclysm, or in increments of very decided displacements. Such faults occur, as far as can be observed, by slow degrees—inch by inch, and sometimes, though rarely, measurable by feet, and covering almost inconceivable periods of time. This being the case it is almost impossible to imagine a condition at any time that would create a lake of any great depth in the Livermore Valley to the east of the fault line due to these movements, as the slowly relatively rising rim would be eroded down by natural processes about as fast as the displacements occurred, or, if not quite as fast, at least slowly enough to permit a filling of the depressed side of the valley floor with ordinary alluvial debris. The records of the wells about Pleasanton, however, are sufficient to discredit any such theory; the logs disclose soils, occasionally clay beds and thick bedded gravels, with no evidence that the clay deposits were lacustrine in origin; in fact, the formation differs in no particular form from the formations in other valleys throughout the State, that resemble this in configuration and conditions of stream flow."

The deposition of clay that takes place under the conditions described by Mr. Mulholland is, therefore, not that a aluminum silicate material—the result of the complete decomposition of feldspar rock, and which is so light that it often remains in suspension for great lengths of time, even in still water—but of fine particles of minerals and rocks in the form of fine sand and silt carried along by the swift moving streams and deposited in lenticular and irregular bodies along its course where the velocity and movement become small. The materials of the true clays may be deposited under these conditions also, but more often the real clay present in these so-called land-formed clays is the result of decomposition of minerals after they have been deposited, and only form a very small per cent of the total bulk as well as only occurring at surfaces exposed to oxidation and weathering.

In addition to being much more pervious on account of the composition and size, land-formed clays have the great advantage of plant and animal growth development through their structure, which is another great factor for such marked contrast in porosity to the common lacustrine clays.

Instances where apparently impervious lacustrine clays have been found by close examination and experimentation to be quite porous, due to the development of plant and animal life, have come to the attention of all engineers, and it is principally to break up the structure caused by this development that puddling is resorted to.

An instance of this has just been brought to my attention by Mr. J. B. Lippincott, of which he writes:

> (Extract from Letter J. B. Lippincott to F. C. Herrmann of July 16, 1912.)
>
> "The day after I left you I went to San Luis Obispo to investigate the water leakage in the oil reservoir which we were testing with water. This reservoir was made in an adobe flat by excavating some eight or ten feet of soil from the center, and using selected material to make dykes around the side. It was then roofed over in order to prevent evaporation losses from the oil. We found that our water in this reservoir was dropping at the rate of a quarter of an

inch per day, and floats indicated that the seepage was occurring through a certain piece of ground about fifty feet in diameter. This was near the center of the reservoir and at the lowest point, and as the area of the water surface contracted the rate of fall on the water surface increased, which indicated that the leakage was occurring through some rather definite and small outlet. We thereupon drew off the water and excavated the soil at this point. It was a sandy clay which had the appearance of being fairly tough and impervious, but which showed, on analysis, that it contained about 35% of clay, the rest being sand and silt. The interesting feature of this soil, however, when we come to examine it, was that it was filled with worm holes. These holes were close together and by taking a small glass dropper, such as you fill a fountain pen with, we could take a fragment of this soil, drop some water in the upper end of one of these small holes and observe the water run through the clod. This soil came from a depth of from eight to ten feet beneath the original surface of the ground. Probably underlying this was a stratum of gravel or sand through which the water was disappearing. At any rate, it was a very clear illustration of exactly what we were talking about in the Livermore country and confirmed the ideas that I previously had on the subject."

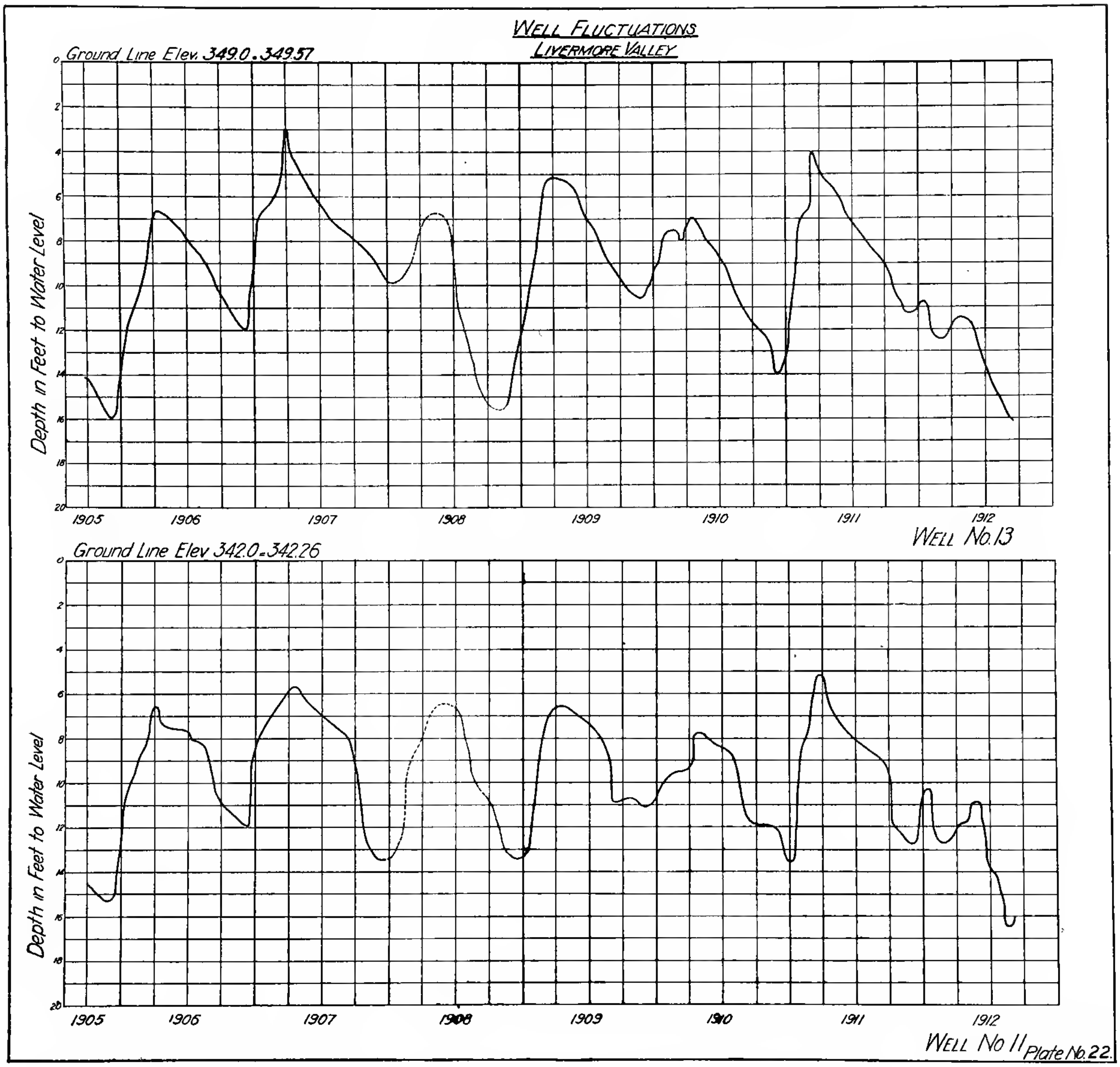
Permeability Due to Plants and Animal Life.

Vegetation, in its growth, carries on an endless process of extending its roots and rootlets through the soil in all directions and to great depths. After they have performed certain functions they die and decay, then sending others to meet the same fate. This process is augmented by the abundant growth of animal life in the form of worms and burrowing species which tunnel through the soil in their search for the minute roots. In this way is created a vast network of minute tunnels and shafts, as it were, through which water may find ready egress. In lacustrine deposits this effective plant and animal life develops only after the formation assumes a position above the lake surface because of an uplift or other cause, and this development extends only to a limited depth. With the land-formed deposits the porous structure extends through their entire depth, as at no time during the many ages of formation were the constructive agents absent. As the streams build up the formation, placing perhaps a few inches or feet during one season, then divert to some other quarter for a year or greater period, the tunneling process is allowed to continue uninterruptedly; then again, the streams shift back in their oscillating motion, more material is placed over the first—perhaps this time coarse gravel instead of the fine sands and silts—covering the vegetation, which decays and again leaves avenues of easy egress for the waters; here, then, is a combination of all of Nature's forces trying to produce a material through which the waters falling upon the earth's surface can find escape, while with the lake-formed deposits the opposite occurs, for here are laid down deposits, the sole purpose of which seems to be to retard and prevent the escape of water.

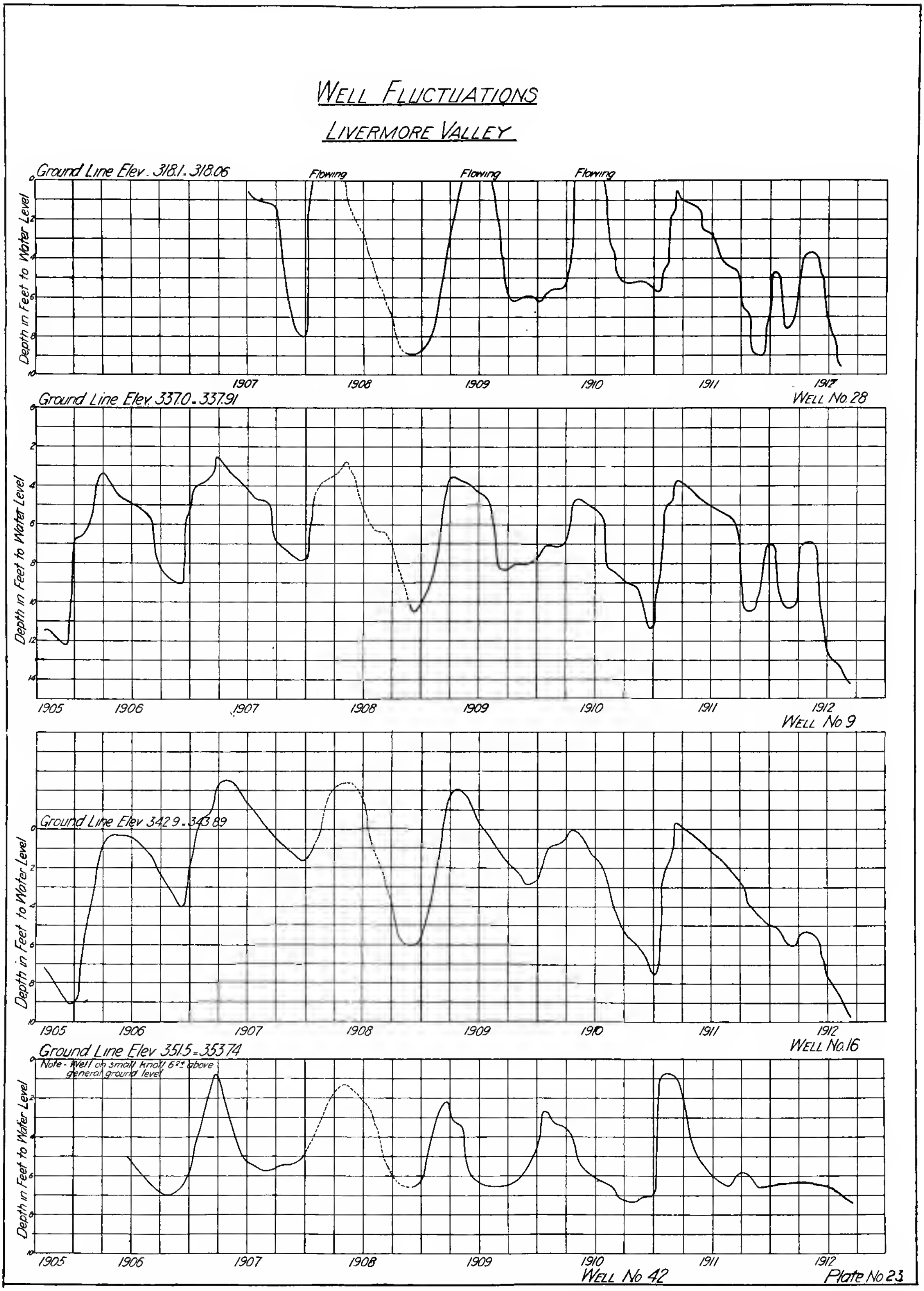
Evaporation from Saturated Soils Can Be Stopped.

The loss of water through evaporation and transpiration from the saturated area at the western end of the Livermore Valley may, by lowering the water table, be stopped and the water utilized. The amount of this loss has varied as conditions of drainage have developed.

The official map of Alameda County in 1874 shows a swamp of 2136 acres, while the testimony of old residents around Pleasanton is that the area was much larger. Mr. Peach, who has had charge of much of the drainage for the Alameda Sugar Company since 1891, indicates an additional area of 1600 acres, which, he says, was a part of the swamp at the time of his going to the valley. Another record of this original swamp is the survey made by G. F. Allardt, County Surveyor of Alameda County, in 1880. This survey shows an area of 1340 acres of tule and willow swamp, with an additional area of 400 acres saturated lands subject to overflow, supporting a dense growth of vegetation. The tule swamp condition continued until about the year 1906 or 1907. Since that time the extreme surface drainage of this area has gradually become effective and cultivation followed. A survey made in June of this year, after an unusually dry winter, shows an area of 8259 acres from which evaporation is taking place. Over 255 acres of this area the water table is between 0 and 2 feet from the surface, over 2538 acres be-



THE FLUCTUATIONS IN THE WELLS SHOW THEIR QUICK RESPONSE TO THE DISCHARGE OF WATER INTO THE GRAVELS.



THE QUICK RESPONSE OF THE WELLS IN LIVERMORE VALLEY INDICATE VERY POROUS AND OPEN GRAVELS WITH LARGE STORAGE CAPACITY.

tween 2 and 6 feet, and over 5466 acres between 6 and 9 feet from the surface.

Evaporation from Saturated Soils is Very Great.

Without actual field measurements to determine the amount of evaporation from this area, we must be guided by results obtained at other places. Because of their geographical position and climatic conditions, we have chosen the records of water surface evaporation obtained by Mr. C. E. Grunsky at Kingsburgh, California, by the California Experiment Station at Berkeley, and by Mr. Edwin Duryea in the vicinity of San Jose, California, as most nearly representing the area under consideration. Mr. Duryea carried on experiments over three areas tributary to Coyote Creek and found the water surface evaporation to be 44 inches, 45 inches and 52 inches per year. Mr. Grunsky, in his experiments at Kingsburgh, California, found an average annual evaporation of 49 inches.

The Berkeley experiments conducted at the University of California for the U. S. Irrigation Investigation under the direction of Dr. Samuel Fortier, gave an evaporation of 41.5 inches. Dr. Fortier, now Chief of the U. S. Irrigation Investigation, is one of the foremost authorities on irrigation and has made extended studies of evaporation from soils.

In view of these records of average annual evaporation we estimate 48 inches as being a very close approximation of the average annual water surface evaporation in Livermore Valley.

For detailed discussion of evaporation, see Appendix "D". The problem of determining quantatively the evaporation and transpiration loss from the saturated area in the Livermore Valley is a very interesting one. We have made this determination in two classes: First, the swamp area supporting the dense prolific growth of tule, willow, bullrush, wild celery, etc., and second, the less saturated alkaline areas of salt grasses and kindred plant life.

From a study of available data shown in Appendix "D" we have accepted for that area, covered by vegetation common to swampy conditions, a transipration of 66 inches per annum or 1.38 times that from free water surface (48"). In determining the evaporation from the rest of the area we are guided largely by results obtained in Owens Valley over areas covered with salt grass, and have accepted 52.53 inches as being the annual evaporation when the water table is at the surface. This evaporation decreases directly in proportion to the depth until at nine feet it is zero.

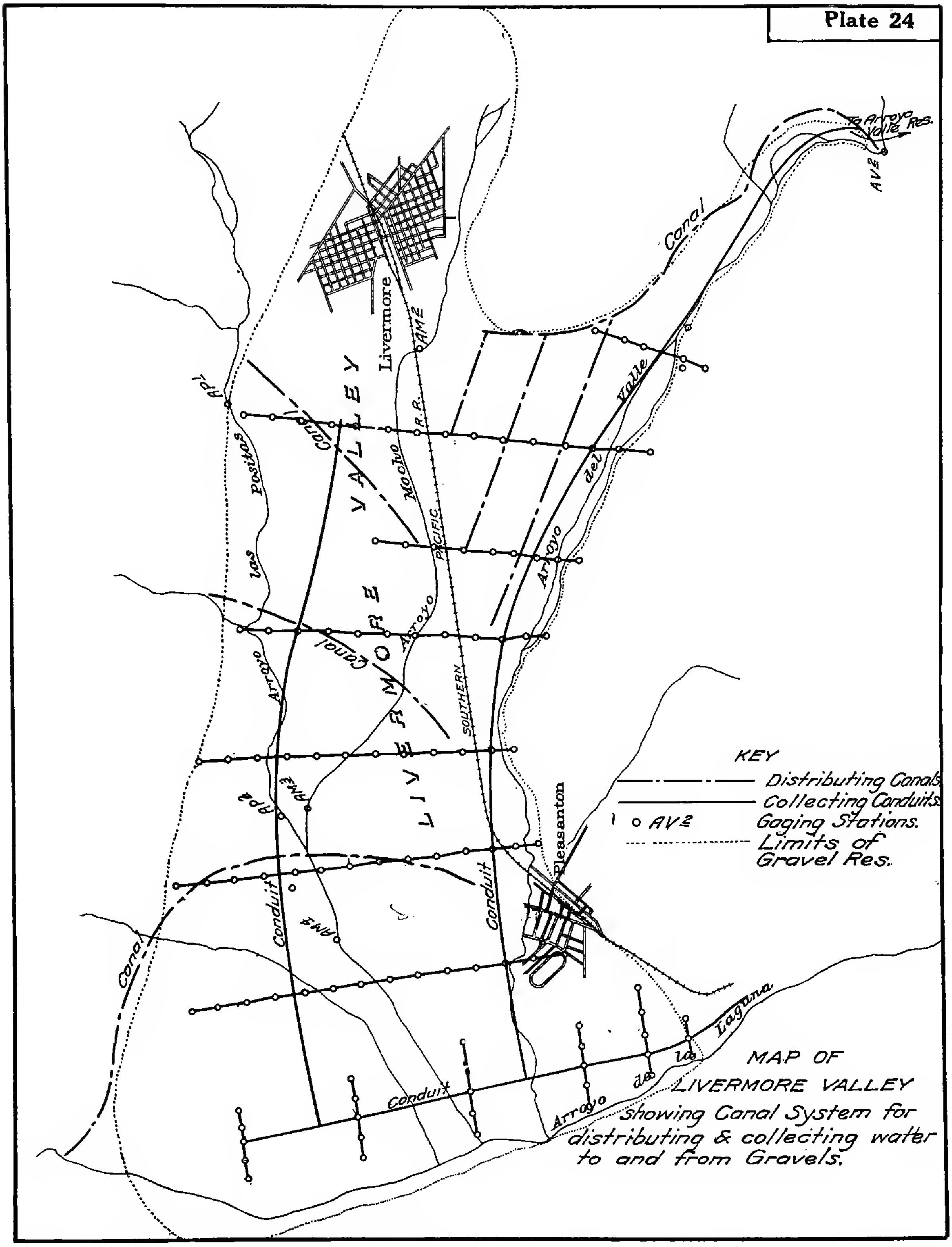
The tabulation below shows the evaporation computed under the conditions of the three surveys. The total area in acres over which evaporation occurs in the survey of June, 1912, is accepted for the other two surveys; this is obviously low as with a higher water table the area would increase.

EVAPORATION FROM SATURATED AREA OF LIVERMORE VALLEY.

Enclosing contours.	Average water depth.	Area in acres.	Evaporation. Depth in Inches.	M. G. D.	
0—2 ft.	1.5 ft.	255	66.0	1.24	Survey of
2—6 ft.	4.0 ft.	2,538	29.5	5.57	June 13-17,
6—9 ft.	7.5 ft.	5,466	9.0	3.66	1912.
		8,259		10.47	
0—0 ft.	Surface	1,340	66.0	6.58	Allardt
0—9 ft.	4.5 ft.	6,919	26.5	13.63	Survey of 1880.
		8,259		20.21	
0—0 ft.	Surface	2,136	66.0	10.48	Alameda Co.
0—9 ft.	4.5 ft.	6,123	26.5	12.06	Official 1874.
		8,259		22.54	

Inspection of the hydrographs of the well measurements over the artesian area for several years past, as shown on Plates 22 and 23, indicates that the average position of the water table is more than four feet above what it was at the time of the survey of June 13-17, 1912. Also that during the summer months, when the evaporation is the greatest, it was as much as eight to ten feet higher. A study of the profiles further shows that, because of the vast network of drainage ditches, this water table rises less rapidly when within a few inches of the surface. All data indicate that the average annual evaporation, under the present conditions, is as much as, or more than, the 20 million gallons per day computed for the condition indicated from Mr. Allardt's survey.

This 20 million gallons per day is supplied from the water product of the catchment areas tributary to Livermore Valley, though because it has escaped through the atmosphere it has not entered into the measured run-off below Sunol. Because of this, the actual amount of water



WITH ONLY NOMINAL DEVELOPMENT BY SIMPLE CANALS AND DITCHES THE ABSORBTIVE GRAVELS OF THE LIVERMORE VALLEY WILL DRINK IN VASTLY MORE WATER THAN AT PRESENT.

produced from the 620.5 square miles of the Alameda System is greater by 20 M. G. D. than is indicated by the 23-year. discharge record of Alameda Creek below Sunol. Therefore, instead of an average daily run-off of 145 M. G., as determined in Appendix "B", the total gross water crop of the Alameda System is approximately 165 M. G. D.

The loss of water through evaporation and transpiration from the saturated area at the western end of Livermore Valley estimated to average 20 M. G. D. during the past 23 years, with sufficient storage capacity, can be saved by lowering the water table and sustaining it at a lower level.

Storage in Upper Gravels Alone is Enormous.

The older Pliocene gravels are undoubtedly saturated with water and may be drained of great quantities. Dr. Branner believes they will support arterian wells. For the purpose of this report, however, we consider only the upper 100 feet of the recent loose alluvial valley fill which we may expect to utilize as the bulk of our working underground reservoir. From a study of all the obtainable geological information and an extended personal examination I am of the opinion that a conservative estimate of the extent of this ultra-porous area covers 30 square miles. The map shown on Plate 24 indicates this area. Within this area I have not included a considerable area of the porous fill where the Mocho, Valle, and Seca Creeks emerge from the hills, and which will absorb run-off whose final destination is the gravel reservoir.

One method of estimating the storage capacity of this reservoir is by a determination of the porosity of the loose alluvial fill. Over the eastern portion of the reservoir the data are far too limited to do more than suggest the general character of this fill. But in the Spring Valley Water Company's properties there are enough records to show the geology to a depth of upwards of 100 feet.

The logs of many wells west of the Santa Rita-Pleasanton road, selected at more or less regular intervals over the area and representing average conditions, show the average per cent of coarse material to be 28 per cent, the lowest per cent being 10, and the highest being 44. The mean depth of these wells is 82 feet.

The logs of wells to the east of Santa Rita-Pleasanton road are not nearly so numerous, and their logs in many cases are not obtainable. Twenty-six wells, with a mean depth of 82 feet, scattered rather irregularly over the valley floor above Pleasanton, show an average of 29 per cent of sands and gravels. This corresponds so closely with the lower area that it is fair to assume 28 per cent sands and gravels as applying to the whole reservoir.

Numerous experiments to determine the voids in sands and gravels give results that vary from 30 to 40 per cent. The average of eight porosity tests made on the Mocho gravelly sandy loam showed 34.1 per cent of voids. And 28 tests of "Livermore gravelly sandy loam" showed 27.3 per cent of voids. A conservative estimate of the voids capable of depletion would then be 25 per cent of the sands and gravels and 10 per cent of the remaining less porous materials, or 14 per cent of the total bulk. Fourteen per cent of the cubical capacity of an area of 30 square miles to a depth of one foot is 876 million gallons, or for a depth of 100 feet it is 87,000 million gallons. Because of the fact, as Dr. Branner states, that "it is impossible to draw cross-sections of the Livermore Valley from the well logs available, showing the disposition of the gravel, sand and clay, no better estimate of the available storage may be made".

In analyzing the absorbing capacity of this reservoir, two divisions readily suggest themselves: the highly porous gravelly and sandy materials of the Mocho and Livermore soils, and the more dense soils composed of clays, adobes and loams. By consulting the soil map it will be noticed that the first class comprises a greater part of the reservoir area east of the Santa Rita-Pleasanton road, while the latter includes the area to the west of this road. It is over the first area that we propose to spread the flood waters of the wet season.

Actual Measurements Prove Great Porosity of Gravel.

A survey made during March of this year showed that 80.5 million gallons of water disappeared into an area of less than one million square feet of the Arroyo Valle channel in 27

hours, or at the rate of 10 cubic feet per square foot of superficial area per day, or equivalent to the water velocity of about 30 feet per day. At this rate, 1 square mile would absorb over 2000 million gallons per 24 hours. Mr. Fred H. Tibbetts, C. E., in a report made in 1907 on the artesian basin of the Livermore Valley, cites an instance of absorption in the stream bed of the Arroyo Valle, of which he writes:

> "The first (stream) measurements on January 14, 1906, were made about 18 hours after the first flood of the season had commenced. The measurements at the Cresta Blanca Bridge showed a discharge of about 1136 cu. ft. per second. At Pleasanton about 600 cu. ft. per second. The seepage loss indicated was 536 cu. ft. per second, or over 47%."

The avidity with which these gravels absorb water, as shown by these flood measurements, even after the flood had been pouring into the gravels for 18 hours, indicates how very porous these gravels in this reservoir must be. Still this is hardly more astonishing than the observation made by Mr. J. B. Lippincott and myself on January 27th, 1912, when we witnessed a flow of 45 sec. ft. of water completely disappear into the gravels of the Arroyo Valle stream bed in a length of 3000 feet. The porosity of these gravels, where they lie under the so-called clay-cap, is shown to be at least as much by the measurements of the underground water velocities in these gravels made by Mr. F. H. Tibbetts, in 1906. Using the Schlicter method (the same as used by the U. S. Geological Survey) he found velocities of the underground waters as follows:

Date of measurement.	Well No.	Velocity, feet per day.	Direction of flow.
Feb. 22, 1906.......	7	24.5	Southwest
Apr. 9, 1906.......	9	22.6	S. 15° W.
Aug. 1, 1906.......	9	25.1	"
Apr. 8, 1906.......	13	10.9	Southwest
June 20, 1906.......	13	15.2	"
July 19, 1906.......	13	19.4	"
May 5, 1906.......	26	43.6	"
Aug. 16, 1906.......	26	57.1	"

In his investigation of the underground waters of Long Island, Mr. J. R. Freeman in his "New York's Water Supply", page 540, says:

> "This proves that near the conduit line the water must be moving seaward at the rate of about one mile per year, or about 15 feet per 24-hour day; but this is the place of maximum velocity, for obviously as we go north the volume of water passing a given vertical east and west section rapidly becomes less as the northern border of the watershed is approached, while the depth of the saturated gravel probably lessens in smaller degrees."

The remarkable freedom with which the water passes through the Livermore gravels even as compared with the Long Island supply, shows how very open they must be, and what an enormous amount of water they hold.

Under the present conditions, both as to soil and saturation, the flood waters of the creeks on the northern side of the valley pass over the adobe soil, of the northern part of the valley to Laguna Creek, down which they escape. These soils are by no means impervious. They are common in all California valleys. Around the margin of Santa Clara Valley, noticeably in the eastern and southeastern part are to be found adobe soils much more dense, and containing much more clay, than do these in question, and the Santa Clara Valley adobes absorb practically all the water running off the slopes of the adjacent mountain sides.

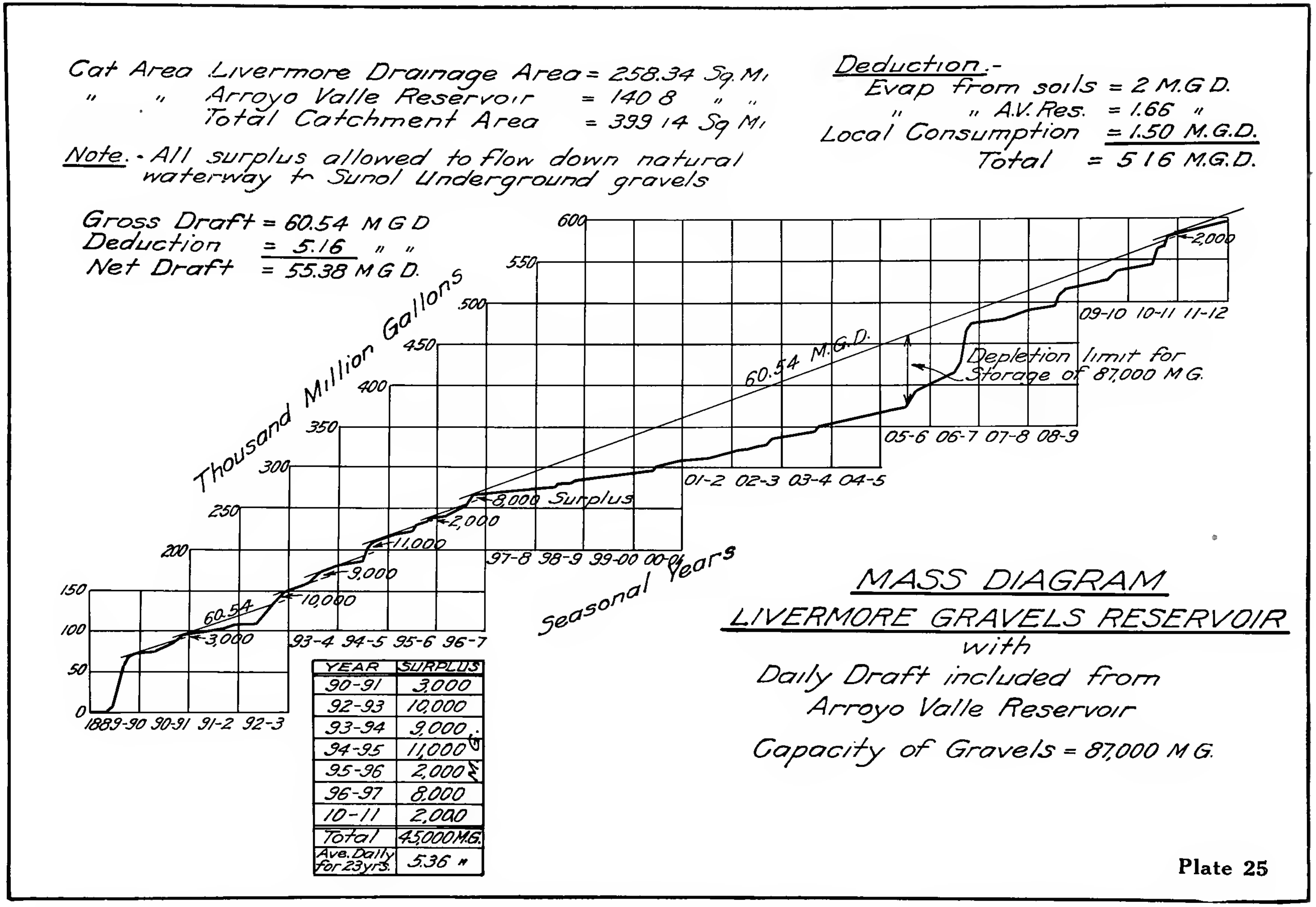
This is further demonstrated by the fact that adobe soils lend themselves very readily to irrigation, and it is well known by experienced irrigators that adobe soils drink up as much water, if not more, than do lighter soils.

A portion of the flood waters of the Arroyo Valle are absorbed by its gravelly beds and the rest passes on to the Laguna Creek and escapes, and all the waters of the Mocho are absorbed by the gravels so long as they are not completely saturated.

Broad Irrigation Will Assist Storage of Flood Waters.

To prevent this waste of flood water we have outlined a canal system shown on map on Plate 24, to spread the water. This indicates the waters of the Alamo being diverted soon after they leave the hills and carried by canal in a general southeasterly direction to spread over the lands north of Pleasanton which are now saturated by artesian waters.

With a depleted reservoir there will be no hindrance of these flood waters sinking to the



LIVERMORE VALLEY GRAVELS IN CONJUNCTION WITH ARROYO VALLE REGULATOR WILL SAFELY YIELD OVER 55 MILLION GALLONS DAILY.

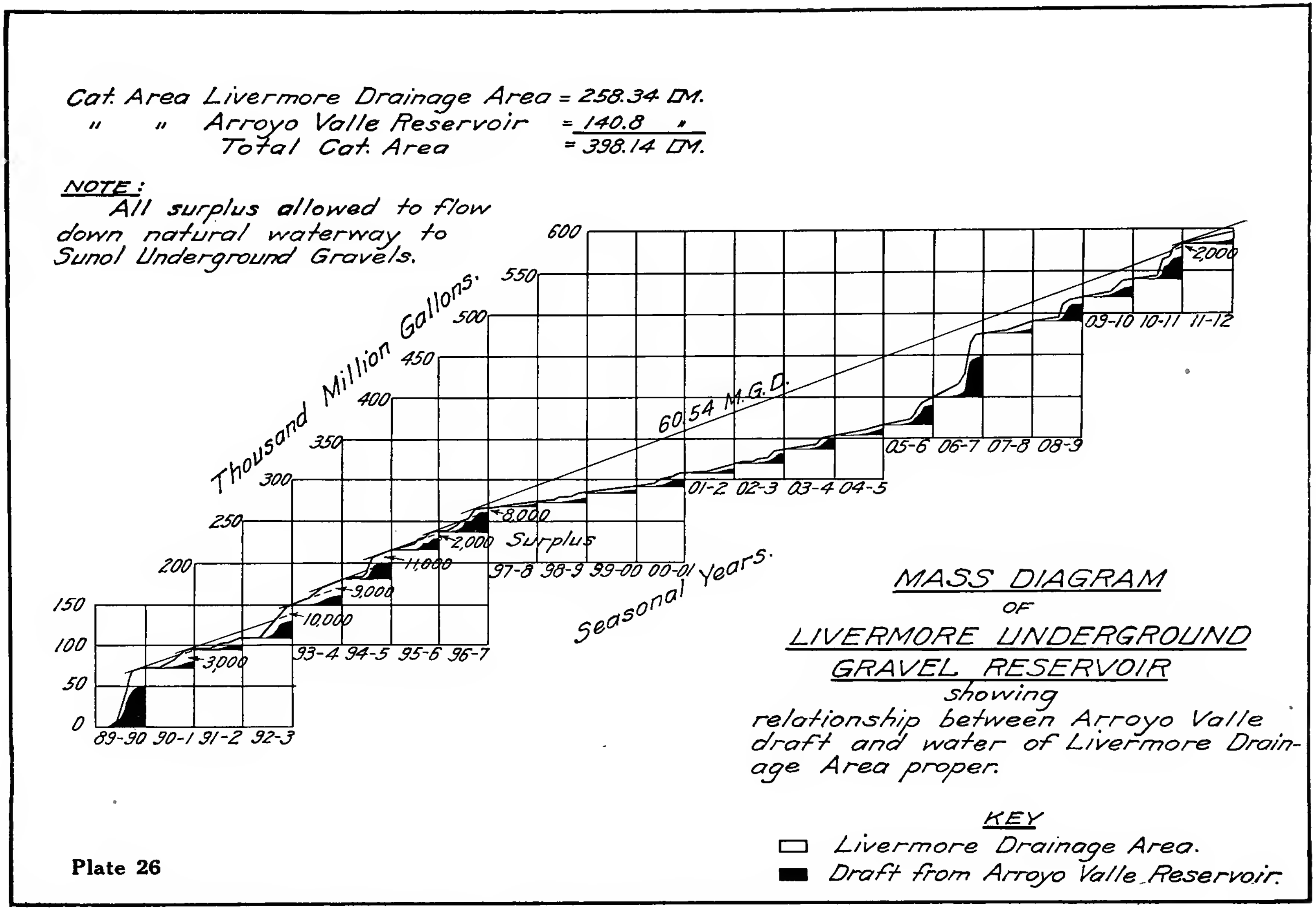


Plate 26

REGULATION AT ARROYO VALLE RESERVOIR SIMPLIFIES STORAGE OF WATER IN LIVERMORE VALLEY.

lowered water table through the same channels by which the artesian waters now rise. In like manner the waters of the Las Positas and Cottonwood Creeks will be carried by canal as shown on the map to the porous gravelly beds west of Livermore.

The Arroyo del Valle is the most important single producer of the Livermore Valley. Flood discharge at the rate of 3000 M. G. D. was measured in the Arroyo Valle, for short duration, on March 23, 1907. This represents a run-off of something over 20 M. G. D. per square mile. If the intensity of this flood be doubled it would be 40 million gallons per square mile per 24 hours, or about 5500 M. G. D. Those extreme floods are very rare and their peaks would perhaps last but a few hours. At present these flood waters pass down over the absorbent beds, in much too large quantities for the porous gravels to completely absorb, to Laguna Creek. On the above mentioned map is shown a system of canals capable of spreading these flood waters over 3 square miles of the gravelly surface of the valley floor. This area, together with the 30 million square feet of the stream channel between Cresta Blanca bridge and the gravel pits absorbing water at only three-quarters the rate measured in March, 1912, or 1500 million gallons per square mile per day, can be made to absorb more than 5500 million gallons per day.

As previously stated, the floods of the Arroyo Valle will be regulated by the Arroyo Valle Reservoir, and it has been shown that the rate of discharge from the Arroyo Valle will by this means be reduced to about 250 M. G. D., or approximately 400 cubic feet per second. At the rate at which the flood of March, 1912, entered the gravels in the Arroyo Valle Creek bed (10 feet per day per square foot) a stream of this size, under the same conditions, would be absorbed by less than 100 acres of gravel. If by reason of the different conditions this rate of absorption be decreased to one-half that measured in March, 1912, a stream of 250 M. G. D. would be absorbed in less than 175 acres. One square mile would absorb it if the conditions were so unfavorable as to permit of a velocity through the gravels of only 1¼ feet per square foot per day.

The Arroyo Valle is by far the largest water producer of the streams tributary to Livermore Valley, so it will be readily seen that a provision of 3 square miles of superficial area of gravels is ample to absorb all the waters fed into it.

Livermore Gravels Will Safely Yield Over 55 M. G. D.

Using the Arroyo Valle Reservoir as a regulator, the run-off of the catchment area tributary to the Livermore underground gravel reservoir of 399.14 square miles, is shown in the form of a mass diagram on Plate 25.

The mass run-off line is formed by adding the run-off of all the catchment areas tributary to Livermore Valley, except that of Arroyo Valle above the Reservoir, to the draft from the Reservoir, as shown on Plate 17, the Arroyo Valle Reservoir being used as a regulator.

On mass diagram Plate 26 are shown these two divisions of run-off, *i. e.*, that from the Arroyo Valle Reservoir and that from the rest of the catchment area tributary to the Livermore Valley, and it will be noted that for nearly one-half the seasons shown, the water product from these two divisions would have been approximately equal. For 6 years the water product from the catchment area above the Arroyo Valle Reservoir would have been considerably in excess of that from all the rest of the tributary catchment areas combined, and for 5 years the reverse would have happened, so that over the whole period these two divisions about equal each other in water production.

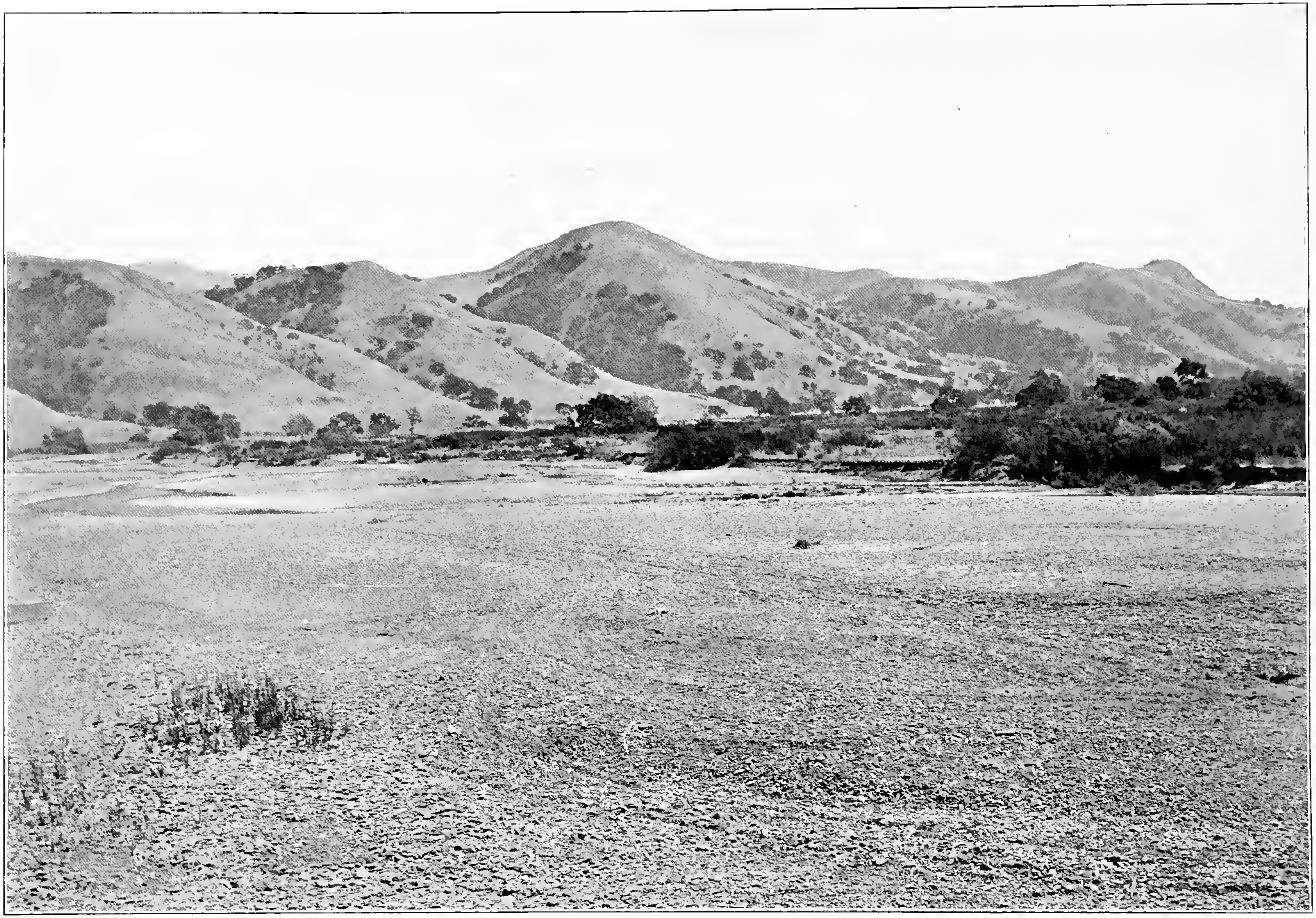
By reference to the mass diagram, Plate 25, it is seen that the years of light flow occurred between the seasons 1897-98 and 1904-5, and this period determines the gross draft that may obtain without drawing upon more than the 87,000 M. G. storage, within the 100 foot depth. This is a purely arbitrary limit and not the limit, by any means, of practicable pumping.

From the mass diagram it is seen that the gross draft is 60.54 M. G. D.

From 1891 to 1897 there are 8 years when the gravel reservoir will always be full.

From 1897-98 to 1904-5 the draft will be greater than the inflow for *each* season, and the plane of saturation will gradually recede, until at the end of the summer of 1905 the limit of the 87,000 M. G. of storage is reached.

In the season 1905-6 and 1906-7 the flow into



SUNOL GRAVEL BEDS.

The Location of the Gravels with Respect to the Watershed is Favorable for Large Catchment.

the gravel reservoir is in excess of the draft to such an extent that by the end of the season 1906-7 the reservoir is nearly full.

From the season 1906-7 to 1909-10 the flow into the reservoir is practically equal to the draft, and in the following season, 1910-11, the reservoir is completely filled, beside a surplus of 2000 M. G.

This unit of the Alameda System, when developed, will be so operated that the line of saturation on top of the 100-foot prism used as a reservoir will be kept at least 9 feet below the surface of the ground.

In this way, as has been done in other parts of California, the loss due to evaporation from saturated soils, which during the past 23 years is estimated at 20 M. G. D. will be prevented. This loss is fully discussed elsewhere in this report. It is probable that this will not be wholly successful, though fortunately any surface saturation that does occur will be in the winter months when evaporation and transpiration loss it at a minimum. This is also true of any evaporation loss that may occur in spreading the waters over the gravel surface.

With efficient operation under complete development, it is believed that the loss due to evaporation from saturated soil will average much less than 2 M. G. D.

By reference to the mass diagram of the Arroyo Valle Reservoir, Plate 17, it is seen that in using this reservoir as a regulator, the draft is seldom large. For the most part it may be easily carried in a moderate sized conduit to the main artery, which will collect the water from the Livermore gravel reservoir. Loss due to evaporation from this source will, therefore, only occur to a small degree and for the purpose of this estimate may be neglected.

A liberal allowance for local consumption in the Livermore Valley is 1½ M. G. D.

It is estimated that by using the Arroyo Valle Reservoir as a regulator the evaporation from it will be 1.66 M. G. D.

To get the net safe yield, therefore, it is necessary to deduct 5.16 M. G. D. from the gross draft of 60.54 M. G. D., from which the net safe yield becomes 55.38 M. G. D.

Surplus from the Livermore Underground Reservoir occurs as follows:

Season.	Mil. gals.
1890-91	3,000
1892-93	10,000
1893-94	9,000
1894-95	11,000
1895-96	2,000
1896-97	8,000
1906-07	2,000
1910-11	13,100
Total	58,100

This total, if spread over the period of 23 years, will average about 5½ M. G. D. This surplus flows into the Laguna Creek and does its share in sustaining the storage in the Sunol gravels.

Water Will be Extracted by Pumps.

Water will be extracted from the Livermore Underground Reservoir by means of a series of pumping stations drawing water from lines of wells across the valley floor, somewhat as indicated on Plate 24.

By distributing the wells properly and operating them in harmony, the surface of the water plane may readily be controlled. By controlling the water surface, the loss due to evaporation from saturated soil surface, previously discussed, will be eliminated. The water so pumped will be gathered by conduits which lead to the main conduit from Pleasanton to Sunol and thence to San Francisco.

Sunol Gravels Are Very Deep.

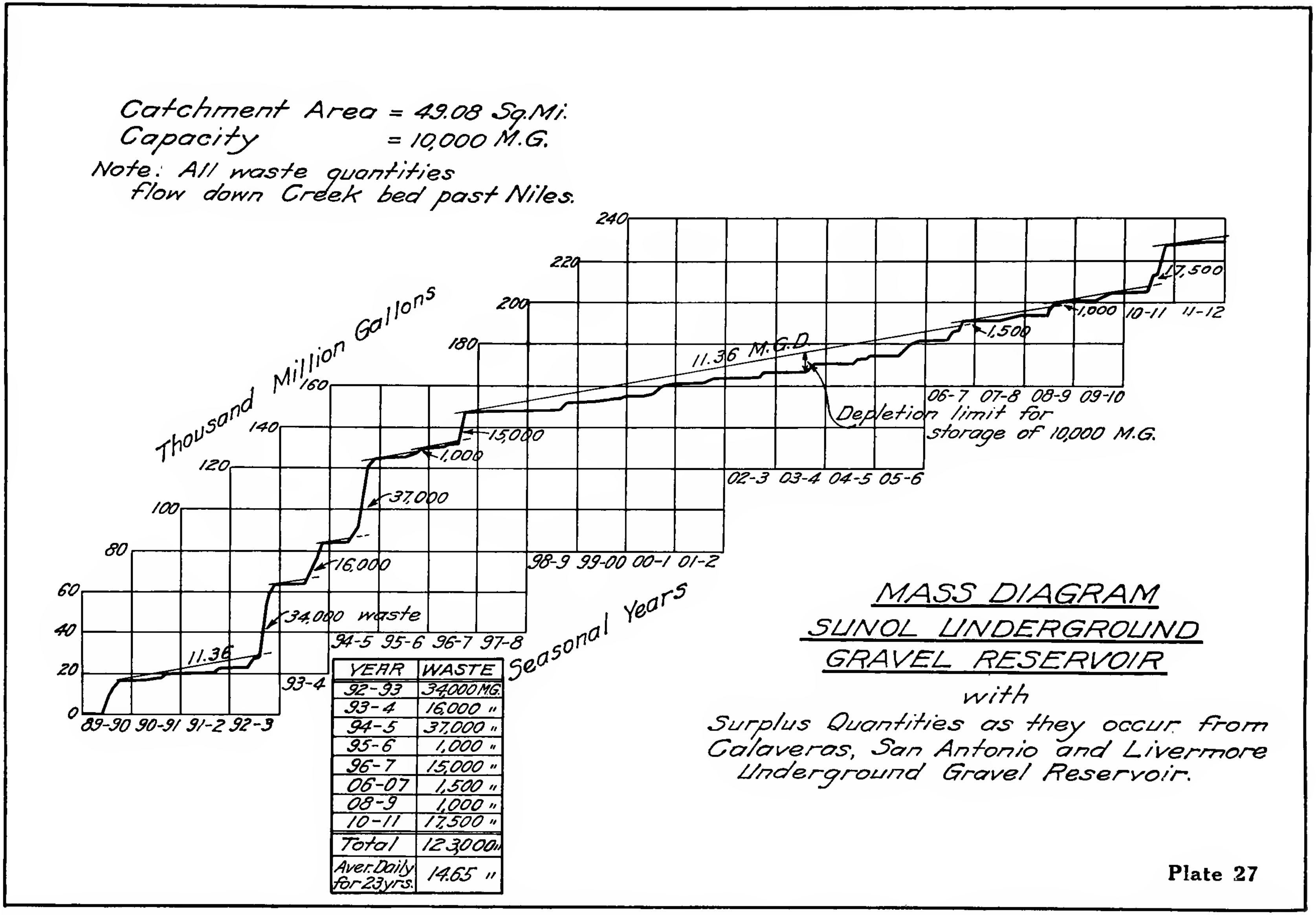
The Sunol Underground Gravel Reservoir has been briefly discussed under "Storage", in this report.

Dr. Branner states that, "similar to the Livermore gravels, the Sunol gravels are of great depth".

Recent borings show that these gravels are very much deeper than we previously believed.

So far, only approximately the upper 20 feet have been drawn upon, their function being to serve as an enormous filter through which the surface water of the Alameda System passes, before being conveyed to San Francisco.

Obviously none of the great storage lying below the filter galleries, and which Nature has provided for us, can be utilized without pumping. But by this method the gravels may be depleted, and the basin serve to conserve the floods and the surplus waters from the Calaveras and San Antonio Surface Reservoir, and the Livermore Underground Reservoir. Consequent-



YEAR	WASTE
92-93	34,000 MG.
93-4	16,000 "
94-5	37,000 "
95-6	1,000 "
96-7	15,000 "
06-07	1,500 "
08-9	1,000 "
10-11	17,500 "
Total	123,000 "
Aver. Daily for 23 yrs.	14.65 "

THE DEEP GRAVELS AT SUNOL WILL SUSTAIN A DRAFT OF OVER 11 MILLION GALLONS DAILY. THE WASTE DOWN NILES CANYON WILL AVERAGE NEARLY 15 MILLION GALLONS DAILY.

ly, this becomes a purely storage reservoir, from which filtered water will still be drawn.

Sunol Gravels Will Safely Yield Over 11 M. G. D.

Plate 27 shows a mass diagram of the summation of seasonal run-off of the Sunol drainage, together with the surplus water from other reservoirs, as determined in the preceding pages of this report.

From this diagram we see that the period of low flow which tests the reservoir most severely is between the seasons 1897-98 and 1905-06.

With a storage of 10,000 M. G., as shown heretofore, and starting with a full reservoir in the season of 1889-90, a safe gross yield of 11.36 M. G. D. may be made upon the reservoir with the following result:

From 1889-90 to 1892-93, the draft will be slightly in excess of the inflow. From the season 1892-93 to 1894-95 considerable waste will occur each season. In the season 1895-96 the draft and inflow are about equal. In the season 1896-97 there is again waste. From the season 1897-98 to the season 1905-06 the draft is equal to, or in excess of, the inflow, with the result that, at the end of the summer of 1905-6, all of the 10,000 M. G. of storage have been used. In the seasons of 1905-6 and 1906-7 the inflow is greatly in excess of the draft, causing the reservoir to fill and waste during the season 1906-7. From 1906-7 to 1910-11 the inflow is in excess of the draft, causing small waste in 1908-9 and great waste in 1910-11.

Because of their great porosity, even at the surface of the ground, no capillary tubes will form in the Sunol gravels, and any evaporation will, therefore, be negligible, and the safe net yield of the Sunol Underground Reservoir is equal to the gross yield, or 11.36 M. G. D.

Following is a tabulation of waste that passes down the Niles Canyon on its way to San Francisco Bay:

Season	M. G.
1892-93	34,000
1893-94	16,000
1894-95	37,000
1895-96	1,000
1896-97	15,000
1906-07	1,500
1908-09	1,000
1910-11	17,500
Total	123,000

Distributed over the 23 years this amounts to 5350 M. G. per year, or 14.6 M. G. D.

Alameda System Will Safely Yield Over 135 M. G. D.

The Calaveras Reservoir, with a storage capacity of 55,000 M. G., may be depended upon for a safe net yield of 60.14 M. G. D.

The San Antonio Reservoir, with a storage capacity of 11,674 M. G., will safely yield 8.92 M. G. D.

By utilizing the Arroyo Valle Reservoir as a regulator in conjunction with the Livermore Underground Gravel Reservoir, which, by drawing to a depth of only 100 feet, has a storage capacity of 87,000 M. G., the Livermore gravels may be made to safely yield 55.38 M. G. D.

The Sunol gravels, if used as a reservoir instead of purely as a filter bed, and drawing a depth of only 100 feet, will make available 10,000 M. G. storage and will safely yield 11.36 M. G. D.

COYOTE RIVER SYSTEM.

The Coyote River rises just south of Mount Hamilton and flows in a general southeasterly, westerly, and northwesterly direction for a distance of about 30 miles, where it debouches into the Santa Clara Valley at a place about 70 miles southeast of San Francisco, commonly called the Upper Gorge.

After entering the valley it flows northwesterly through the valley trough emptying into the southerly extremity of San Francisco Bay near the town of Milpitas. That part of the river above the Upper Gorge and lying wholly within the mountains is referred to as the Upper Coyote, whose tributary catchment area is 193 square miles. About 11 miles upstream from the Upper Gorge, at damsite "D", it is proposed to construct the Coyote Reservoir, having a storage capacity of about 9100 M. G., as shown on Plate F-4, its relation to Coyote catchment area being shown on Plate F-1. The reservoir has a tributary catchment area of 115 square miles, which in topography is very similar to that of the Calaveras catchment area, though not quite so productive of water.

The seasonal precipitation over this catch-

ment area as indicated by records given by Messrs. Haehl and Toll in Vol. 61 of the Transactions of the American Society of Civil Engineers, is in excess of 26 inches, or about 2 inches less than that of Calaveras. Actual gagings covering a period of 7 years and made in conjunction with the precipitation records, above mentioned, are available for this analysis.

Detailed discussion of the computations of precipitation and run-off are given in Appendix "F", prepared by Mr. H. Monett, of the Engineering Corps of the Spring Valley Water Company.

From these computations has been prepared a mass diagram, Plate F-3, showing the cumulative run-off of the Coyote Reservoir for the 23 years, 1889-90 to 1911-12. On this diagram is also shown the dependable draft that may be made from this reservoir. The gross draft is 23.01 M. G. D., which after allowing for evaporation, at the liberal rate of 48 inches per season, is reduced to a net draft of 21.16 M. G. D.

Waste occurs as follows:

Season.	M. G.
1889-90	32,000
1890-91	2,000
1892-93	4,500
1894-95	1,000
1895-96	10,200
1896-97	7,600
1898-99	2,500
1902-03	3,600
1905-06	11,000
1906-07	32,000
1908-09	25,000
1909-10	4,200
1910-11	10,000
Total	145,600

Averaged through the 23-year period this waste amounts to 17.34 M. G. D., which is discharged into the Santa Clara Valley. The contribution from that part of the Upper Coyote lying below the Coyote Reservoir amounts to an average of 28 M. G. D., making a total contribution to the Santa Clara Valley after the Coyote Reservoir is in operation of 45 M. G. D.

ALVISO-RAVENSWOOD SYSTEM.

This system consists of a large body of artesian land surrounding the southern extremity of San Francisco Bay. This territory has been explored by a large number of wells which indicate that a large supply of water may be obtained from this source. As previously stated, for the purposes of this report, I have accepted the estimate of Mr. Hermann Schussler of safe dependable yield of this source which is 21 M. G. D.

SAN JOAQUIN RIVER.

The San Joaquin River is one of the largest rivers in California. It serves a catchment area of 6000 square miles, carrying to the San Francisco Bay all the waste waters from that portion of the Sierra Nevada Mountains lying south of the Calaveras River.

Always Available for Distant Future.

It lies about 20 miles east of the Livermore Valley, and at such time in the remote future, when the needs of San Francisco shall have become equal to the safe dependable yield of the resources of the Spring Valley Water Company, an almost unlimited supply of water may be readily obtained from this source.

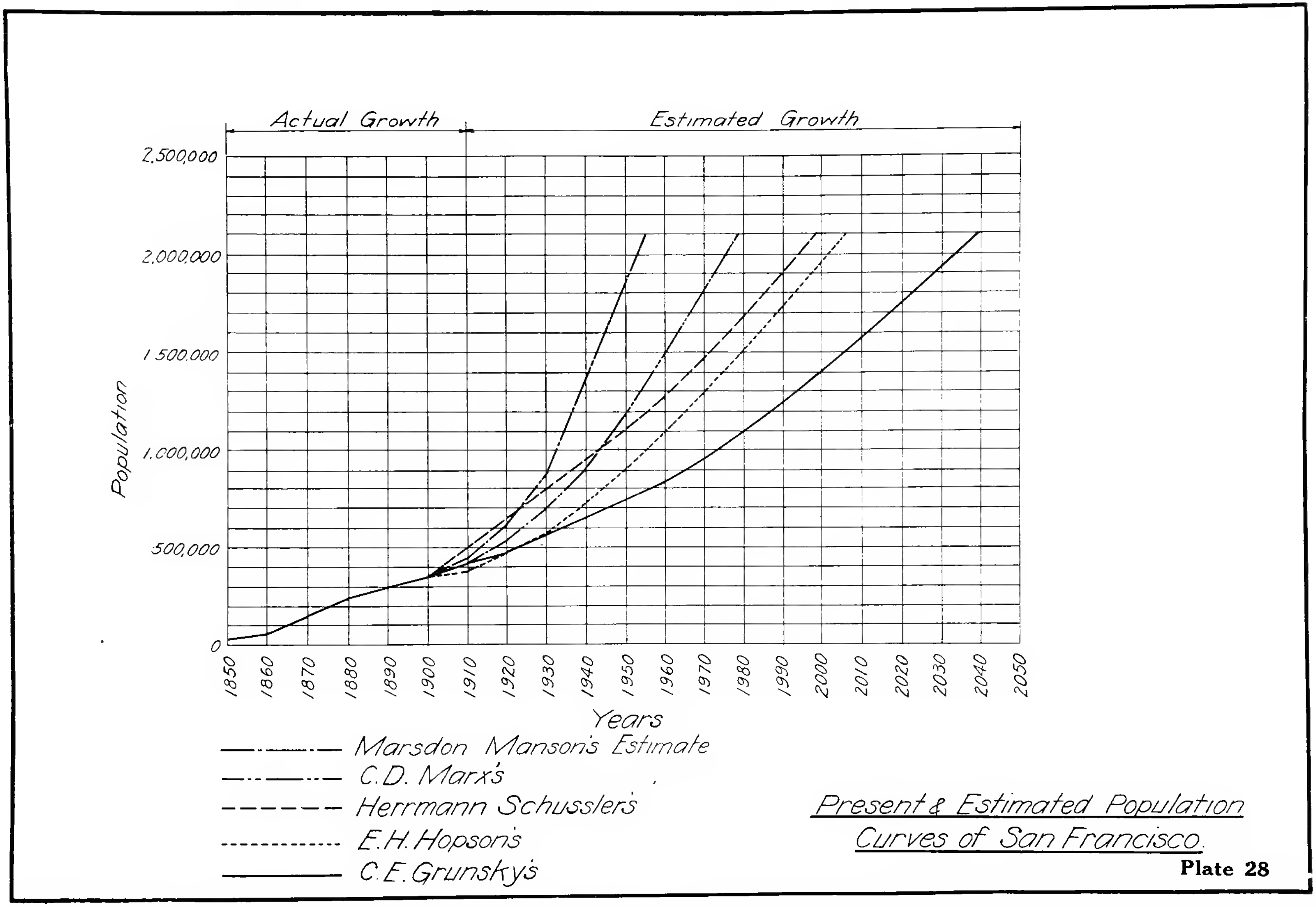
By pumping and conveying only 20 miles this water may be delivered into the Livermore Valley, whence it may be filtered by the unlimited natural filtration gravels and conveyed to the City of San Francisco.

CONSUMPTION OF WATER.

The average daily consumption of water in San Francisco for the year 1911, as indicated by the records of the Spring Valley Water Company, was 37.7 million gallons daily.

During the last few years the consumption has increased at the average rate of about 1½ M. G. D. per annum. For many years the future requirements for San Francisco have been the subject of careful analysis and thought by all investigators of the water supply of this City, and many elaborate compilations and deductions have been made. These results are based upon estimates of increased population and of industrial activity, and at best can be only approximations.

So many unforeseen factors may predominate in a few years, tending either to stimulate or to hamper the growth of a city, that estimates as to the increase in population are but speculative. To this is added the uncertainty as to the change in the per capita consumption, which may be similarly affected by various factors. Among these are the installation of meters, changes in methods of living and industrial development.



THESE CURVES SHOW THE WIDE VARIATION IN THE OPINION OF VARIOUS ENGINEERS AS TO THE PROBABLE INCREASE IN POPULATION OF SAN FRANCISCO.

Estimates of future population of San Francisco have heretofore been very excessive, as shown by those made 30 years ago by eminent engineers who anticipated that the population of San Francisco in 1900 would be 1,000,000, or approximately three times the actual of 1900.

In estimates of the future consumption of water, it has been customary to allow 100 gallons per capita per day, though in his report on "New York's Water Supply", Mr. Freeman estimated that with proper inspection and meters on all taps, from 42 to 67 gallons per capita per day would be ample. Similarly, in 1904, Mr. Dexter Brackett, Chief Engineer of the Metropolitan Water District of Boston, in his report on "Measurement, Consumption and Waste of Water," said that the quantity actually required for all uses in the Boston District was 55½ gallons per inhabitant per day, and that all use above that amount was waste.

At the present time the per capita consumption in San Francisco, as shown by the records of the Spring Valley Water Company, is 84 gallons per day. This low per capita consumption prevails for many reasons, chief among them being:

1. That the cool summers and warm winters prevailing here obviate the necessity of summer sprinkling, and of running water continuously from taps to prevent frozen pipes, as is the custom in most cities.

2. The tendency in San Francisco to house people in flats and apartments, as evidenced by the fact that while 25 years ago there was an average of 6 people to one water service, at the present time the average is 9.

3. The ease with which salt water and poor water from wells may be obtained for condensing purposes in industrial plants.

Taking all these factors into account, as well as the past use of water in San Francisco, we believe that an allowance of 100 gallons per capita per day is a liberal one. At this rate of consumption, the 210 M. G. D. of the Spring Valley Water Company available for the City under complete development will serve a population of 2,100,000 people.

Previous Estimates by Engineers.

Messrs. Hermann Shussler, C. E. Grunsky, Marsden Manson, C. D. Marx, E. H. Hopson have made estimates of the population of San Francisco for various future periods, and none of these estimates is as far in advance as 2,100,000 people. However, by projecting each of their population curves in its same general direction, using constantly increasing increments, we find that they will reach the 2,100,000 population mark, as follows:

Hermann Schussler	1998
C. E. Grunsky	2040
Marsden Manson	1955
C. D. Marx	1978
E. H. Hopson	2005

On Plate 28 are shown the projected curves indicating the estimates of future population made by each of these gentlemen.

If we use a decreasing increment, as Mr. Freeman did in estimating the future population of the so-called Metropolitan District of San Francisco in his report of July 15, 1912, it would be many years after the beginning of the next century before the 2,100,000 mark is reached by all these authorities.

The mean of the five estimates given above gives a population of 2,100,000 to San Francisco City in the year 1995. On this basis, therefore, the present water resources of the Spring Valley Water Company available for the City of San Francisco will be sufficient, when fully developed, to serve this City until about the beginning of the next century.

Plenty of Water for Metropolitan District.

If we take in addition to this amount, that additional quantity available for the Metropolitan District from Spring Valley Water Company sources of 42 M. G. D., making a total of 252 M. G. D., and apply it at the rate of 100 gallons per capita per day to Mr. Freeman's estimate of the future population of the Metropolitan District, as given on page 76 of his report above referred to, we find that water available from the Spring Valley Water Company resources alone will serve this Metropolitan District until the year 1975.

Further, if to the ultimate development of the Spring Valley Water Company we add that amount of water available from other sources, serving, or available to serve, other communities within this Metropolitan District, as indicated

by reports for the City of San Francisco, it will make a grand total of about 350 M. G. D., which, when applied to Mr. J. R. Freeman's population curve at the rate of 100 gallons per capita per day, will supply this Metropolitan area until about the year 2000.

Summary of Conclusions.

Summarizing the results of this report, I find that the Alameda System is capable of furnishing a dependable yield of 135.80 M. G. D.

The Peninsula System, including the coast streams and Lake Merced, may be relied upon for a safe yield of 74.20 M. G. D.

This gives a total of 210 M. G. D. available for the City of San Francisco, which, with the ample per capita consumption of 100 gallons per day, will serve a population of over 2,000,000 people. From an average of the estimates of various engineers, this will occur about the beginning of the next century.

In addition to this there is the combined supply from the Coyote and Bay Shore Systems available for the region around San Jose, which is within the proposed Metropolitan District. This, together with nearby sources other than those of the Spring Valley Water Company, will supply the Metropolitan District with a population of 3,000,000 people, using a per capita consumption of 100 gallons per day. According to Mr. Freeman, this will occur at about the beginning of the next century.

FILTER GALLERY AT SUNOL. JUNCTION OF TWO GALLERIES, SUNOL.
Subterranean Water Being Drawn from the Gravel Fill of Sunol Valley. Nearly Half San Francisco's Water Supply is Thus Drawn Daily.

THE BASIN OF THE WATER TEMPLE AT SUNOL.
Here the Filtered Waters from the Galleries at Sunol Meet the Artesian Waters from Livermore Valley.

PRESENT WORKS OF THE SPRING VALLEY WATER COMPANY WITH THEIR PROPOSED FUTURE EXTENSIONS

Letter of Transmittal.

San Francisco, May 1, 1912.

Wm. B. Bourn, Esq., President of the Spring Valley Water Company.

Dear Sir:—I herewith transmit to you my report of May 1, 1912, on "The Present Works of the Spring Valley Water Company with their Proposed Future Extensions."

The two reports, which I prepared for you during the past year, namely, the report of August 19, 1911, "On the Resources of the Alameda System", and the report of November 14, 1911, "On the Water Resources of Livermore Valley", were brief digests of the respective situations, and were not encumbered by copies of a mass of statistical data, plats, surveys, cross-sections, etc., used in their preparation; as, at your request, they were to be condensed in form, and, owing to the limited time then available, these reports were to be preliminary in their nature.

My report of May 1, 1912, presented herewith, and entitled "The Present Works of the Spring Valley Water Company with their Proposed Future Extensions", outlines the company's general plan of future development of its present and proposed system.

It shows that by this proposed development, the supply capacity of its Peninsular works will, by the development of the Coast Streams, be increased from 22 million gallons, as at present, to fully 70 million gallons per day, and the supply capacity of the Alameda System, from about 16 million gallons as at present to 120 million gallons per day.

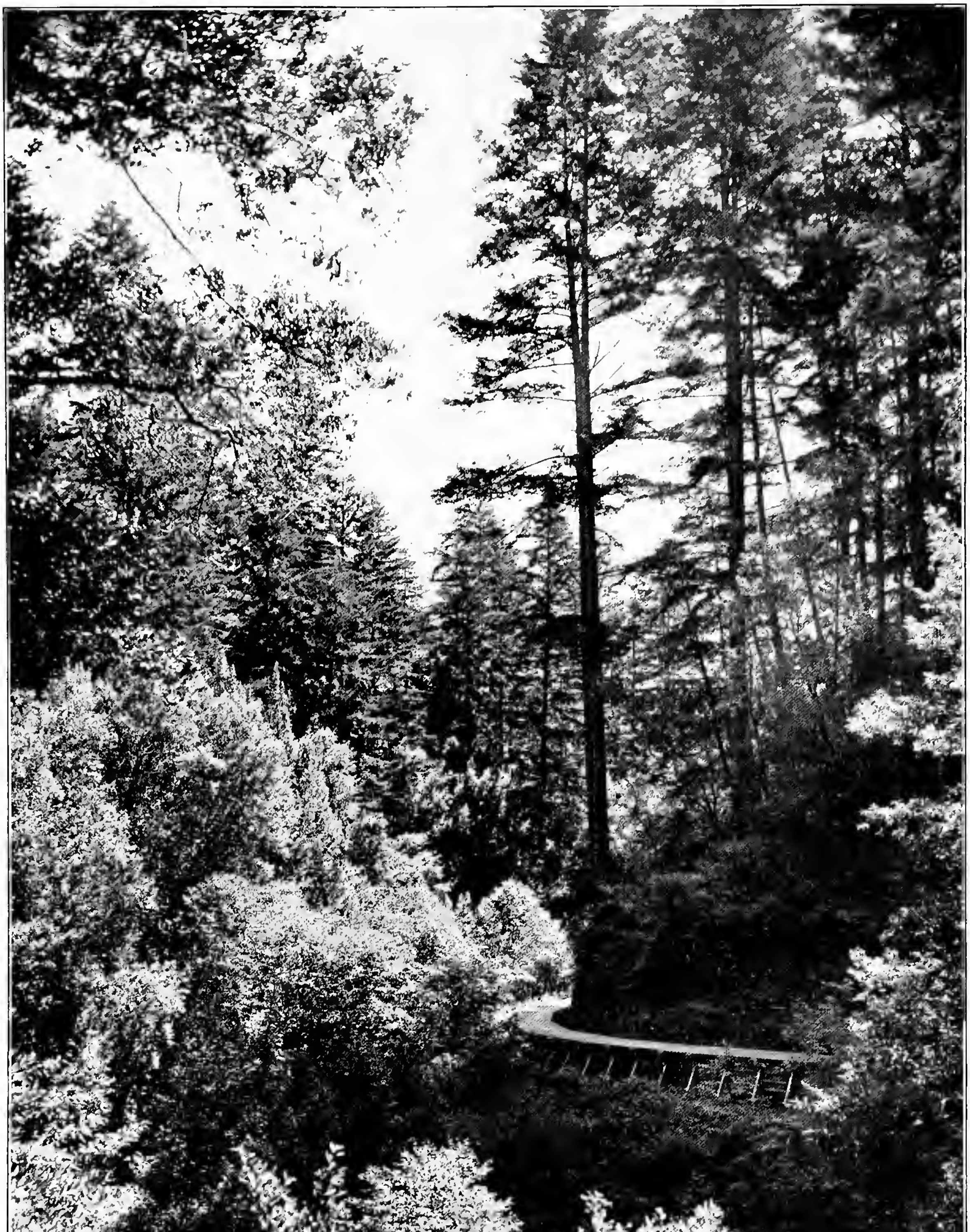
That, when required to add to its system, a practically *unlimited* supply of many hundreds of millions of gallons per day, a portion of the spring freshet waters of the nearby San Joaquin River, will be utilized. The utilization of the supply from the San Joaquin is *only* practicable by the full control and use of the large combined filtration and storage facilities of the Spring Valley Water Company's Alameda and Peninsular Division.

This report furthermore shows that by the development of the company's artesian and other properties around the southerly portion of San Francisco Bay, the large suburban boroughs of *Greater San Francisco* can easily be furnished with a supply of 50 million gallons per day, which will comfortably take care of 500,000 additional inhabitants in that region alone.

The main feature pervading the entire report of May 1, 1912, and one which cannot be too strongly emphasized, is the "Unit idea" of combining the subdivisions of the company's works into *one closely connected and interlocked system,* by which not only the greatest degree of water conservation will be effected, but also that one division can assist the other by either furnishing it with water or storing its surplus waters, thereby reducing waste to a minimum.

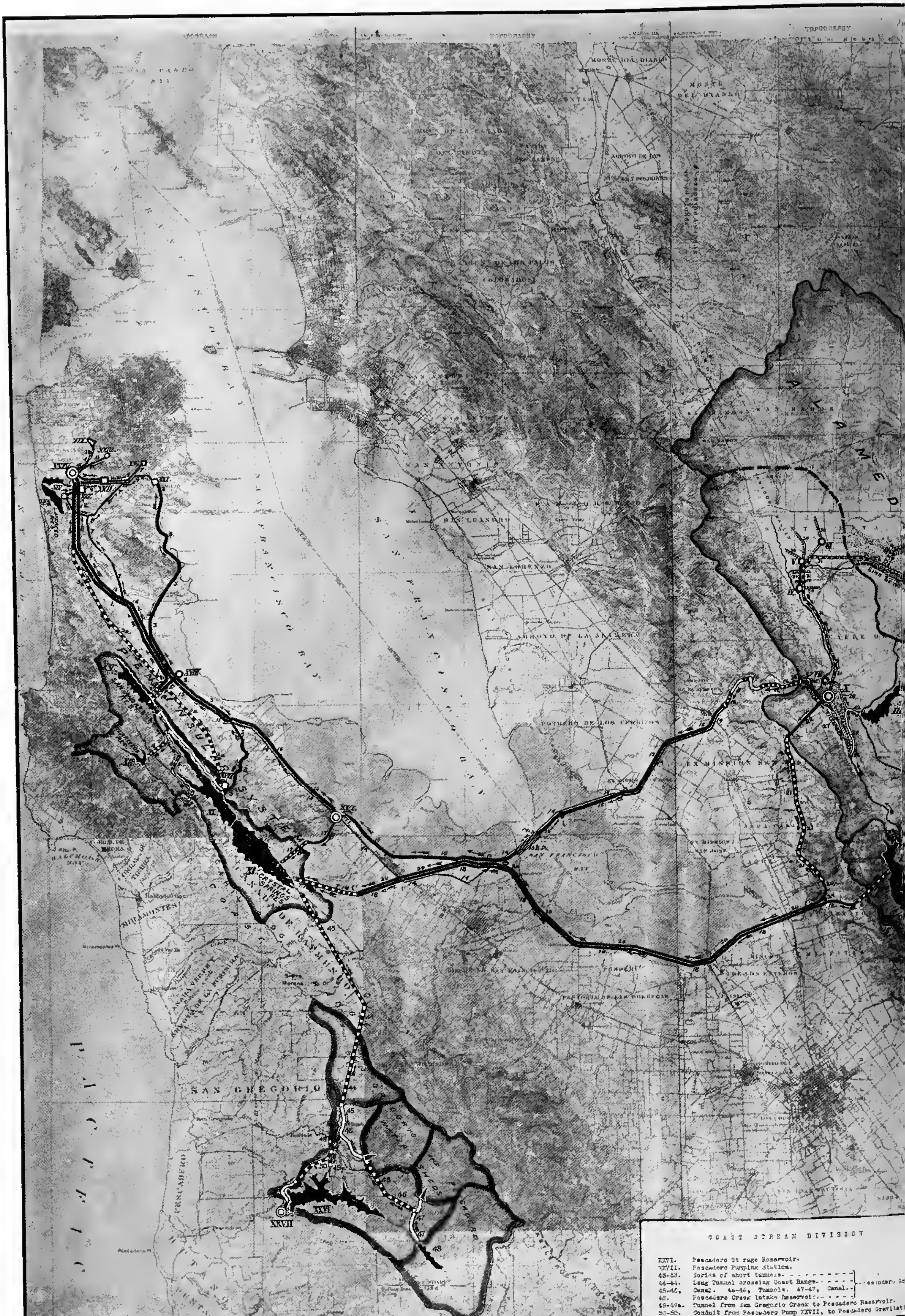
Respectfully,

H. SCHUSSLER,
Consulting Engineer of Spring Valley Water Company.

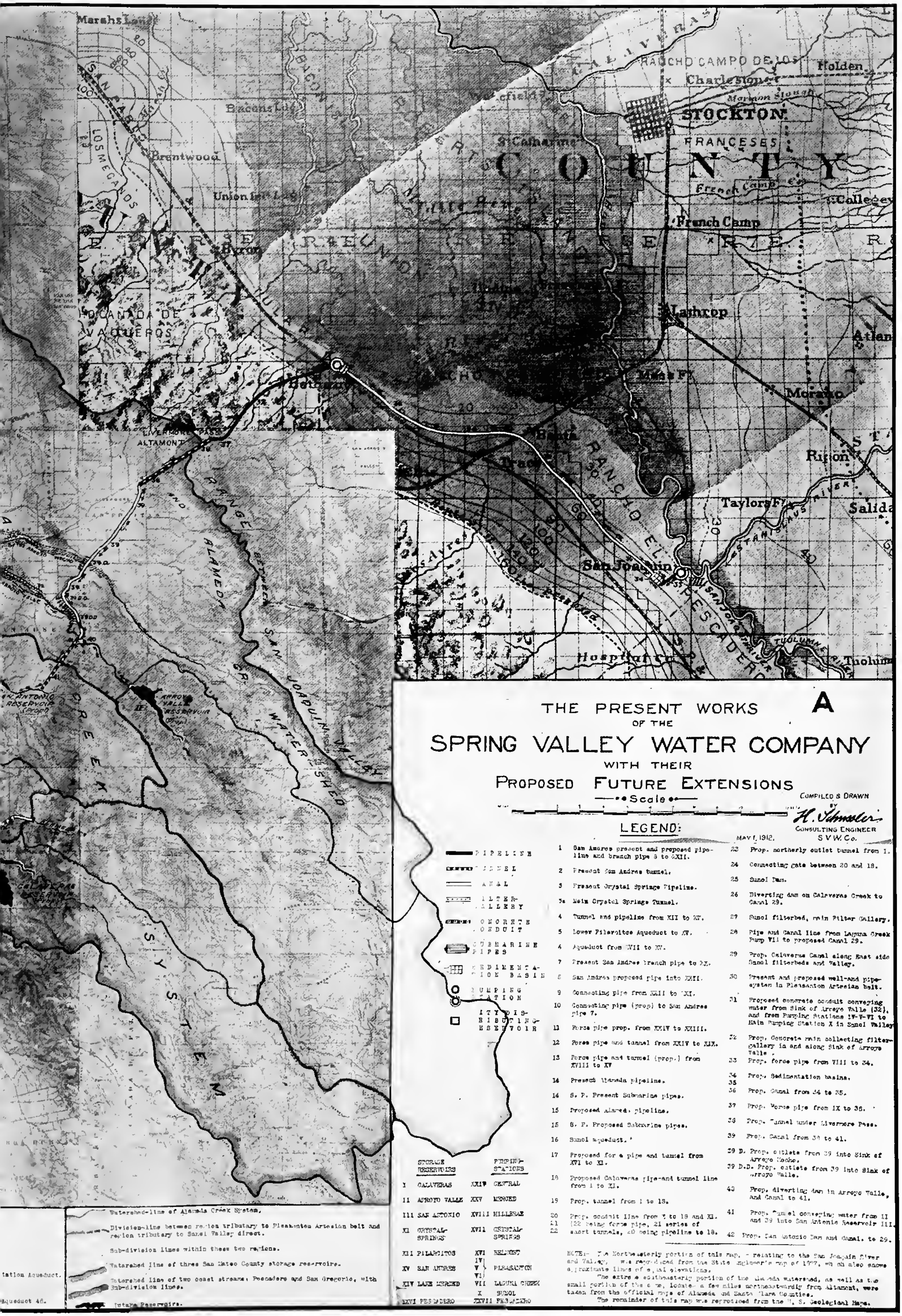


PILARCITOS SIDE FLUME.

In this beautiful region the Spring Valley Water Works began its first operations in the early sixties of the last century.



TOPOGRAPHY
MONTE DEL DIABLO
SAN LEANDRO
SAN LORENZO
ARROYO DE LA ALAMEDA
POTRERO DE LOS CERRITOS
SAN FRANCISCO BAY
SAN GREGORIO
PESCADERO
PACIFIC
COAST STREAM DIVISION
XXVI. Pescadero Storage Reservoir.
XXVII. Pescadero Pumping Station.
43-43. Series of short tunnels.
44-44. Long Tunnel crossing Coast Range.
45-45, Canal. 46-46, Tunnels. 47-47, Canal.
48. Pescadero Creek Intake Reservoir.
49-49a. Tunnel from San Gregorio Creek to Pescadero Reservoir.
50-50. Conduit from Pescadero Pump XXVII, to Pescadero Gravitati


THE PRESENT WORKS
OF THE
SPRING VALLEY WATER COMPANY
WITH THEIR
PROPOSED FUTURE EXTENSIONS
A
Scale
COMPILED & DRAWN BY
H. Schussler
CONSULTING ENGINEER
S V W. Co.
MAY 1, 1912.
LEGEND:
PIPELINE
CANAL
SUBMARINE PIPES
PUMPING STATION
1 San Andres present and proposed pipe-line and branch pipe 8 to XXII.
2 Present San Andres tunnel.
3 Present Crystal Springs Pipeline.
3a Main Crystal Springs Tunnel.
4 Tunnel and pipeline from XII to XV.
5 Lower Pilarcitos Aqueduct to XV.
6 Aqueduct from XVII to XV.
7 Present San Andres branch pipe to XX.
8 San Andres proposed pipe into XXII.
9 Connecting pipe from XXII to XXI.
10 Connecting pipe (prop) to San Andres pipe 7.
11 Force pipe prop. from XXIV to XXIII.
12 Force pipe and tunnel from XXIV to XIX.
13 Force pipe and tunnel (prop.) from XVIII to XV
14 Present Alameda pipeline.
14 S. P. Present Submarine pipes.
15 Proposed Alameda pipeline.
15 S. P. Proposed Submarine pipes.
16 Sunol aqueduct.
17 Proposed for a pipe and tunnel from XVI to XI.
18 Proposed Calaveras pipe-and tunnel line from I to XI.
19 Prop. tunnel from I to 18.
20 21 22 Prop. conduit line from I to 18 and XI. (22 being force pipe, 21 series of short tunnels, 20 being pipeline to 18.
23 Prop. northerly outlet tunnel from I.
24 Connecting gate between 20 and 18.
25 Sunol Dam.
26 Diverting dam on Calaveras Creek to Canal 29.
27 Sunol filterbed, main Filter Gallery.
28 Pipe and Canal line from Laguna Creek Pump VII to proposed Canal 29.
29 Prop. Calaveras Canal along East side Sunol filterbeds and Valley.
30 Present and proposed well-and pipe-system in Pleasanton Artesian belt.
31 Proposed concrete conduit conveying water from Sink of Arroyo Valle (32), and from Pumping Stations IV-V-VI to Main Pumping Station X in Sunol Valley
32 Prop. Concrete main collecting filter-gallery in and along Sink of Arroyo Valle.
33 Prop. force pipe from VIII to 34.
34 35 Prop. Sedimentation basins.
36 Prop. Canal from 34 to 35.
37 Prop. Force pipe from IX to 36.
38 Prop. Tunnel under Livermore Pass.
39 Prop. Canal from 39 to 41.
39 D. Prop. outlets from 39 into Sink of Arroyo Hondo.
39 D.D. Prop. outlets from 39 into Sink of Arroyo Valle.
40 Prop. diverting dam in Arroyo Valle, and Canal to 41.
41 Prop. Tunnel conveying water from II and 39 into San Antonio Reservoir III.
42 Prop. San Antonio Dam and Canal to 29.
STORAGE RESERVOIRS
I CALAVERAS
II ARROYO VALLE
III SAN ANTONIO
XI CRYSTAL-SPRINGS
XII PILARCITOS
XV SAN ANDRES
XIV LAKE MERCED
XVI PESCADERO
PUMPING STATIONS
XXIV CENTRAL
XXV MERCED
XVIII MILLBRAE
XVII CRYSTAL-SPRINGS
XVI BELMONT
IV V VI PLEASANTON
VII LAGUNA CREEK
X SUNOL
XXVII PESCADERO
Watershed-line of Alameda Creek System.
Division-line between region tributary to Pleasanton Artesian belt and region tributary to Sunol Valley direct.
Sub-division lines within these two regions.
Watershed line of three San Mateo County storage reservoirs.
Watershed line of two coast streams: Pescadero and San Gregorio, with Sub-division lines.
Intake Reservoirs.
The remainder of this map was reproduced from the U. S. Geological Maps.
STOCKTON
COUNTY
FRENCH CAMP
Lathrop
Holden
Charleston
Brentwood
Byron
Bethany
San Joaquin
Taylors Fy.
Salida
Ripon
Mossdale
Tracy
ALTAMONT
Marsh's Ldg.
Bacons Ldg.
St. Catharine
Union Isl. Ldg.
CANADA DE VAQUEROS
LOS MEGANOS
RANCHO EL PESCADERO
FRANCESES
French Camp Cr.
Hospital Cr.
TUOLUMNE
Tuolumne
STANISLAUS RIVER
SAN JOAQUIN RIVER
ALAMEDA CREEK SYSTEM
RANGE BETWEEN ALAMEDA AND SAN JOAQUIN VALLEY WATER SHED
ARROYO VALLE RESERVOIR (Prop.)
SAN ANTONIO RESERVOIR (Prop.)

PRESENT WORKS OF THE SPRING VALLEY WATER COMPANY WITH THEIR PROPOSED FUTURE EXTENSIONS

BY

HERMANN SCHUSSLER,

Consulting Engineer, Spring Valley Water Company.

San Francisco, May 1, 1912.

W. B. Bourn, Esq., President, Spring Valley Water Company.

Dear Sir:—The following is an outline of my views as to the best and most economical method of future development of the works of the Spring Valley Water Company.

The Public Misinformed.

The public, in the past and particularly during the last decade, has been persistently misinformed regarding the amount of water which can be developed on the properties owned by the Spring Valley Water Company, thus spreading the erroneous idea that the water supply obtainable from the present and proposed works of the Company would in the near future become inadequate for the needs of San Francisco. I take pleasure therefore in herewith submitting to you the following review on this subject, which deals only with the facts as they exist.

Basic Facts Relating to United System.

In order to fully illustrate the situation it will be necessary to review not only the Company's present and future water product, but also the question of what will constitute an ample supply for San Francisco in the future.

Much has been said in the past on the latter subject, by both the City and the Company.

For the purpose of comparison I shall quote from my testimony in 1904-5 in the U. S. Circuit Court and from my affidavit of June 20, 1908, filed in the U. S. Circuit Court, in both of which my views on the subject are plainly set forth.

Before making these quotations I wish to call attention to the fact that, in order to produce and utilize under our extremely variable climatic conditions *the best average results* from the annual runoff of a watershed, two conditions are necessary, viz: *First,* that *ample storage facilities* are available in order to reduce waste of water during rainy seasons to a minimum while gathering the maximum runoff, and *secondly,* that the annual supply drawn from such storage reservoirs must be of such proportions, *as to make room* in the reservoirs for the runoff of the succeeding rainy season. *Only* by a combination of these two conditions can the waste of water be reduced to a minimum.

The water supply furnished to San Francisco during the past 50 years, which has been mainly based upon a combination of the above two conditions, fully illustrates this principle.

The Company has provided in the past and intends to provide in the future as large storage facilities on its properties as are required and as the topographical and physical conditions permit, in order that *while drawing its water supply from them, to store most if not all of the runoff product* of the succeeding seasons, large average and small.

From the successful experience and knowledge gained on this subject during the past forty-five years on its Peninsular Reservoir System, during which long term the Company has succeeded in reducing the waste of water from its reservoirs to a minimum, coupled with its observations and experience gathered since the season of 1889-90 regarding the runoff and storage conditions on its Alameda Creek System, studies have been made and plans have been prepared

by the Company for the gradual and fullest development of the Alameda System, *and the average daily net water product that can be developed on this system* has been very closely ascertained.

In many of my reports to the Company as well as in my testimony I have placed great emphasis on the principle, that in order to obtain under our variable climatic conditions the best results as to net water yield from the Company's Peninsular and Alameda Systems, it is absolutely necessary to construct and operate the respective works, and connect them with each other in such manner *that both systems will form one complete unit.*

Thus by providing the largest available storage facilities for the main branches of each of the two systems and by connecting both by conduits of capacity ample to convey the water from the reservoirs on the Alameda System into the large Peninsular Reservoir storage which will be provided over and above the requirements for the water product from the direct watersheds of the latter reservoirs, the waste of water from either portion of the combined system will be reduced to a minimum.

Works Constructed and Operated as One Closely Connected Unit.

The following quotations relating to my views on the necessity of constructing and operating the Company's properties and works as *one closely connected unit* are taken from my above mentioned testimony of 1904-5 in the U. S. Circuit Court:

> *Answer to Question No. 919:*—"When in former years the water supply of San Francisco was solely drawn from the peninsula sources, the combination of these reservoirs, watersheds and water rights was always handled, managed and treated as a unit. Since then, owing to the growth of the water consumption in San Francisco, and in order to meet such growing demand, it became necessary to join the supply from Alameda Creek to that from the peninsula, and the two systems have become so intimately connected and interwoven with each other that they can neither be separated nor treated nor valued separately from each other, as they form one inseparable unit and must always be handled and valued as such."
>
> *Answer to Question 923:*—"This unit idea will be still more the case and will be still more accentuated in the future as with the constantly growing consumption the amount of water annually hereafter drawn from Alameda Creek will constantly grow in volume while serving as a feeder to the Crystal Springs reservoir, in which reservoir such waters from the Alameda Creek on their way to San Francisco will be accumulated, together with waters coming from other sources into the same reservoir. This shows that now as well as hereafter, when the works of the Company are eventually completed as contemplated, all of the properties as reservoir sites, watersheds, water rights, rights of way and works are and always will be one inseparable unit. The unity of the entire combination enables the works to furnish an economical, interchangeable, constant, reliable and abundant supply of potable water."
>
> *Part of Answer 958:*—"So that, at any time when required, surplus waters from the Alameda Creek System that would run to waste from the full reservoirs there if no proviso was made on this side of the bay to store such surplus waters, those surplus waters will then be run over and stored in the Crystal Springs reservoir. It is plain, therefore, that the one part of the works, the peninsula part, will then need the Alameda Creek portion for additional supply, while the Alameda Creek portion will need the peninsula system of reservoirs for assisting in the storage of its surplus waters. In that manner, by properly carrying out the very carefully devised plans in the future of gradually, as the City's demand for water grows, increasing the storage facilities on the properties of the company, and also increasing, necessarily, the conduit lines in capacity, the daily supply for San Francisco can gradually, economically, and always ahead of time be brought up to about 135,000,000 gallons a day, which is the probable consumption, as approximately estimated, in about sixty or seventy years from now."

The above quotations from my testimony very clearly and unmistakably show the method by which, and the reasons for which, the Spring Valley Water Company proposes to save most if not all of the runoff waters from both the Peninsular and the Alameda branch of its united system.

As an evidence that this plan had been adopted by the Company a number of years before my above testimony of 1904-5 was given, I will quote from my estimate furnished to the Board of Supervisors at their request, in my report

to them of February 5, 1901, on the cost of gathering and storing water in Calaveras Valley (I on accompanying map) and conveying 30 million gallons per day into Crystal Springs Reservoir (XI on map), and from there to San Francisco.

(See pp. 34-35 of my report of February 5, 1901, to the Board of Supervisors of San Francisco.)

"11,700 feet Tunnel No. 1, capacity one hundred million gallons daily" (19 on map).

"120,000 linear feet, A1 American iron pipe (not steel) 46" clear diameter, capacity thirty million gallons per 24 hours" (18 on map).

"7,000 feet Tunnel No. 2 *of two hundred and fifty million gallons capacity per 24 hours*" (westerly end of 18 on map).

The above quotations show plainly by the large daily carrying capacity of *Tunnel No. 1,* (being the main westerly outlet tunnel of Calaveras Reservoir (19 on map), then planned for a capacity of 100 million gallons per day, *or fully three times the daily capacity of the first 46 inch pipeline,* then proposed to run from there to Crystal Springs Tunnel [T18 on map]) that tunnel 19 was intended to carry principally during rainy seasons *the excess water* of Calaveras Reservoir into the Crystal Springs Reservoir and thus prevent waste from the former reservoir down Calaveras Creek, or at least reduce such waste to a minimum.

The quotations furthermore show that Tunnel No. 2, the main tunnel (T 18 on map) piercing the divide between the Santa Clara Valley and Crystal Springs Reservoir, through which the first as well as future additional pipelines across Santa Clara Valley were to pour the surplus water of the Calaveras Reservoir into Crystal Springs Reservoir, being made of a capacity of 250 million gallons per day, was intended, besides carrying the water from the Coast Stream Project and other sources, to also carry the 100 million gallons per day of storm water eventually to be brought from Calaveras Reservoir via the route 19-18-T-18, the pipe capacity of line 18 meanwhile being increased up to the 100 million gallons per day capacity of Tunnel 19.

Since writing the above report of February 5, 1901, eleven years have elapsed and by a thorough study of the potentiality of the Alameda System during this long intervening period, I became more than ever convinced that my original plan as shown in the above quotations from my above report of February 5, 1901, as well as in my testimony of 1904-5, furnished the most economical, practical and successful method of reducing the waste from the proposed Alameda System (when under its fullest development in the future) to a minimum.

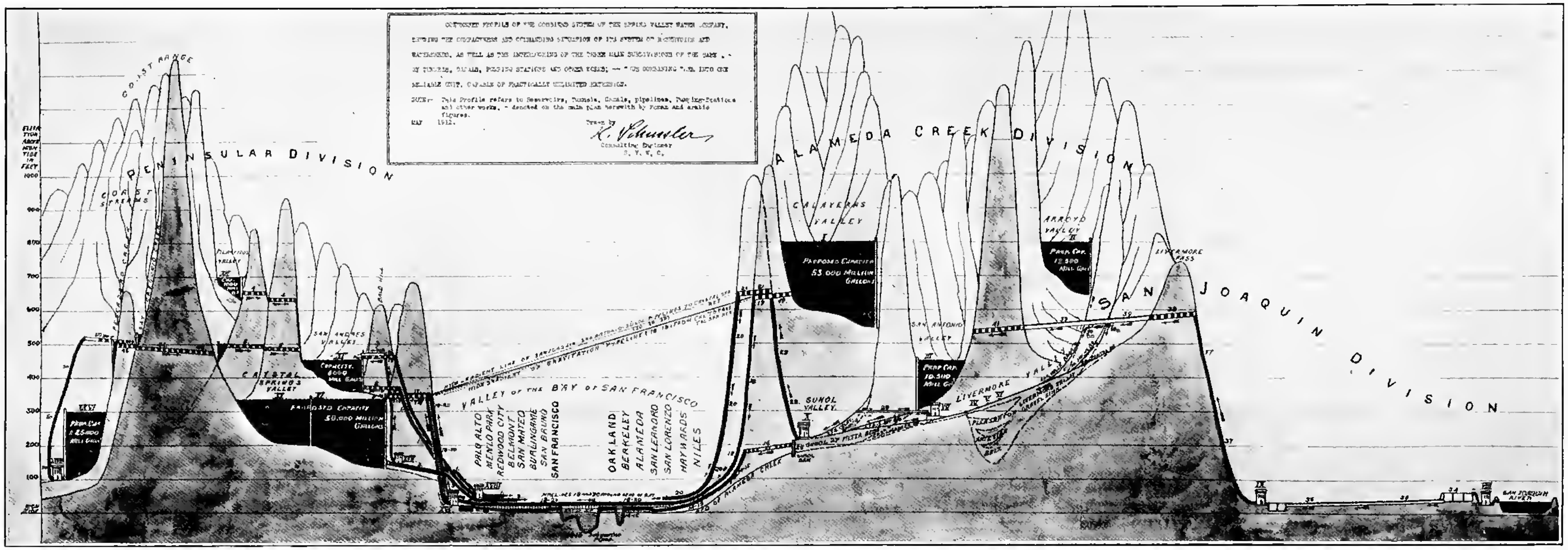
In my report of August 19, 1911, on the resources of the Alameda System (in case the Company should decide to build the Calaveras Reservoir to a capacity of 30,000 million gallons only) I stated that the Calaveras Tunnel (19 on map) might then have to be enlarged to a daily capacity of fully 200 million gallons per day, so as to bring its daily carrying capacity to equal that of three future 60-inch pipes each of 75 million gallon daily carrying capacity.

During the rainy season and whenever there was danger of losing water by waste from the 30,000 million gallon Calaveras Reservoir the full capacity of the Calaveras Tunnel (19 on map) of say 225 million gallons per day could then be discharged through the three 60-inch pipelines (18 on map) across Santa Clara Valley and through the Crystal Springs Tunnel (T-18 on map) into the enlarged Crystal Springs Reservoir.

The Spring Valley Water Company rather than to go to the expense of the third one of these 60" pipelines contemplates increasing the storage capacity of the Calaveras Reservoir by raising the highwater mark to 790 feet elevation above tide, thus giving it a maximum storage capacity of about 53,000 million gallons.

Thus by means of this proposed enlarged storage capacity at Calaveras and the two 60" pipelines to Crystal Springs Reservoir of a joint carrying capacity of 150 million gallons per day (*or from 2½ to 3 times the daily average water product of the Calaveras Reservoir with its feeder from the adjoining Alameda Creek watershed*) the Company by using proper foresight and caution will be able to reduce the waste from the Calaveras Reservoir to a minimum, even during the severest rainy seasons recorded.

Meanwhile the two other proposed storage reservoirs for the Alameda System, viz.: On the Arroyo Valle and on the San Antonio Creeks respectively, will be constructed of a storage capacity of about 12,500 million gallons for the



THE FUTURE SYSTEM OF THE SPRING VALLEY WATER COMPANY.

Condensed Profile of the Combined System Showing the Compactness and Comanding Situation of Its Reservoirs and Watersheds as Well as the Interlocking of the Three Subdvisions of the Same by Tunnels, Canals, Pumping Stations and Other Works, thus Combining Them into One Reliable Unit Capable of Practically Unlimited Extension.

Arroyo Valle Reservoir with a water surface elevation of about 800 feet above tide and of a storage capacity of about 10,500 million gallons for the San Antonio Creek Reservoir, with a water surface elevation of about 445 feet above tide.

Regarding the proposed increase of the storage capacity of the Crystal Springs Reservoir on the Peninsula, in my above mentioned affidavit of June 20, 1908, filed in the U. S. District Court, p. 6, I say on this subject:

> "c. The Crystal Springs of about 19,300 million gallons capacity, which latter capacity, by raising the dam twenty feet, can be easily increased to about 30,000 million gallons capacity and which capacity, by adding a northerly concrete extension to the present dam, and by raising the entire structure 43 feet above its present height of 145 feet, the capacity of the Crystal Springs Reservoir can be increased up to about 45,000 million gallons."

Based upon studies made by me on the subject during the latter part of 1911 the Spring Valley Water Company proposes to still further increase the future storage capacity of the Crystal Springs Reservoir by raising the highwater line of the Crystal Springs Reservoir to an elevation of 340 feet above tide (instead of 323 feet, as shown in the above affidavit), for which raising, the present dam is of ample cross section and strength, thereby increasing the storage capacity of the Crystal Springs Reservoir to about 58,000 million gallons.

RECAPITULATION OF THE ULTIMATE PROPOSED STORAGE CAPACITIES OF THE COMPANY'S RESERVOIRS.

By the construction of the three proposed storage reservoirs on the Alameda Creek System, viz.: The Calaveras, Arroyo Valle and San Antonio, and by increasing the storage capacity of the Crystal Springs Reservoir as above outlined, the following total joint storage capacity will be created to which the combined runoff product of the Alameda and Peninsular Systems will be made tributary.

PROPOSED STORAGE CAPACITY IN MILLIONS OF GALLONS (ROUND FIGURES).

	M. G.
Alameda Creek System—	
Calaveras Reservoir	53,000
Arroyo Valle	12,500
San Antonio	10,500
Crystal Springs	58,000
To which must be added—	
San Andreas Reservoir	6,000
Pilarcitos "	1,000
Lake Merced Reservoir, (present capacity 2500 million gallons) which can very easily and economically be enlarged by raising the lake surface between 15 and 20 feet, to	5,000
Thus creating a proposed *total storage capacity* of the (3 Alameda and 4 Peninsular) reservoirs combined of	146,000

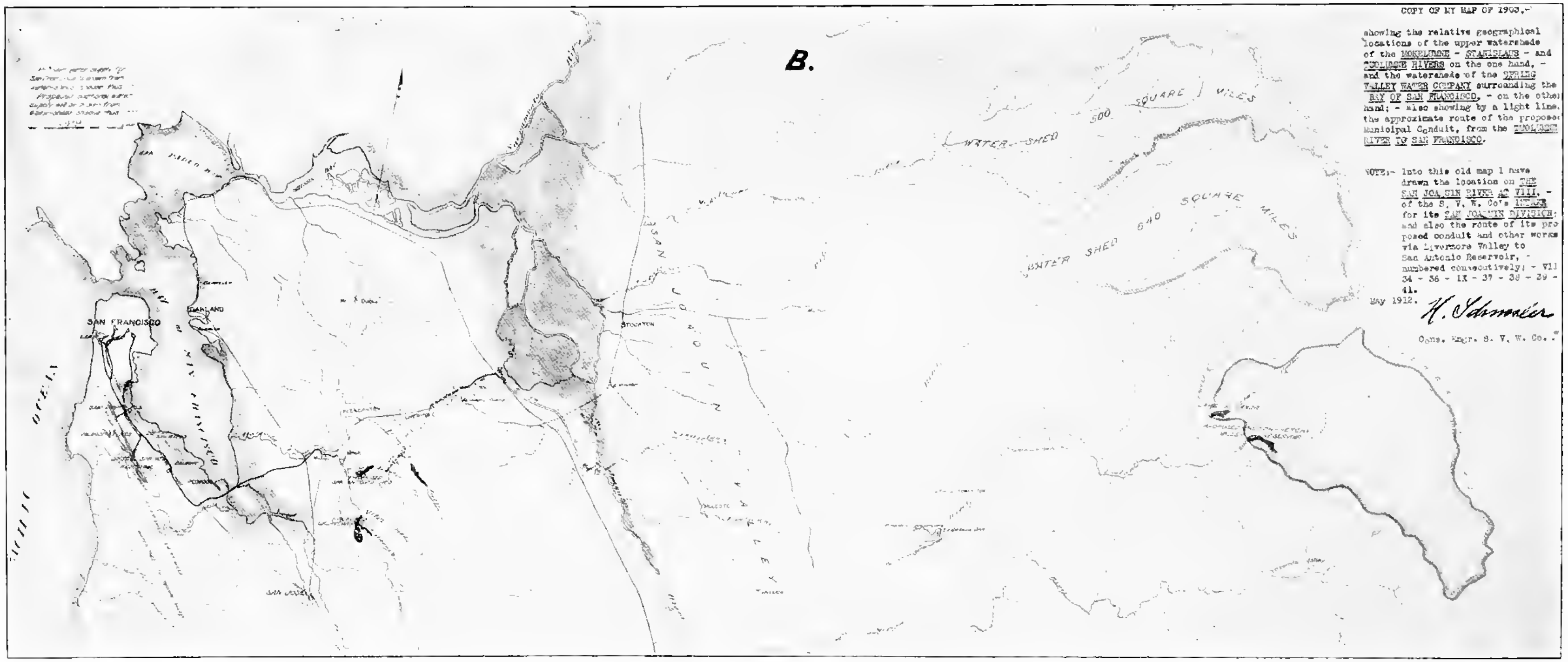
If at some time in the future Lake Merced Reservoir should be eliminated from use for domestic supply purposes then in that case the above proposed total storage capacity of the remaining six reservoirs, viz: Calaveras, Arroyo Valle and San Antonio on the Alameda Creek Branch, and Crystal Springs, San Andreas and Pilarcitos on the Peninsular Branch of the entire United System will be 141,000 million gallons, or in round figures 140,000 million gallons.

THE FUTURE DEVELOPMENT OF THE PRESENT AND PROPOSED RESOURCES OF THE SPRING VALLEY WATER COMPANY.

As fully shown in the first portion of this report the future development of the Company's present and proposed resources will proceed successively as the demand for water increases, while combining and operating all branches of its system as *one complete unit,* thus continuing the same method of operation as has been employed in the past.

For the purpose of meeting the daily requirements of San Francisco proper, culminating about the year 1950, in a minimum supply of 110,000,000 gallons per day from the combined Peninsular and Alameda Creek System alone, and without the development of the coast streams or other present or proposed resources of the Spring Valley Water Company, the Company proposed at that time to gradually develop the Alameda Branch of the system, by successively building storage reservoirs at Calaveras, San Antonio and Arroyo Valle, by which works the resources of the Company's Alameda System would have been partly increased.

The full development of the Alameda System would follow thereafter whenever required, as it was then expected that long before that period the complete ownership of the properties and rights requisite for such additions would be vested in the Company.



MAP SHOWING RELATIVE GEOGRAPHICAL LOCATIONS OF SIERRA SY STEMS TO SPRING VALLEY WATER COMPANY SYSTEM.

The San Joaquin River as a Future Addition.

This latter source which I investigated from time to time since 1877 and early came to the conclusion that by using the Alameda System with its unparalleled gravel deposits acting as natural filter systems, and with its compact artesian and reservoir system lying just to the west of the San Joaquin Valley, through which latter from four to six months in spring and summer of each year a vast amount of water passes on its way from the melting snows of the Sierra to the sea, the natural next step of a successful water supply *having the present Spring Valley System as a basis,* would be to make the floodwaters of the San Joaquin River tributary to the filter and reservoir systems of the Alameda Creek region, and to the Crystal Springs and San Andreas Reservoirs, on the Peninsula.

Owing to the subterranean natural filtering system of the Company in both Livermore and Sunol Valleys, and owing to the facility with which the waters from the San Joaquin could either be passed through the natural filtering process in Livermore and Sunol Valleys direct, or passed partly through the filtration and artesian process of the Livermore Valley and partly (with or without the waters from Arroyo Valle Reservoir) into the San Antonio Reservoir, and from there to and through the Company's natural filtering process in operation in Sunol Valley, this proposed addition of the *San Joaquin during its freshet stage,* offered to the owners of the Spring Valley Water Company's properties on the Alameda System and on the Peninsula a most effective, rapid and economical addition to its works with a supply capacity of almost unlimited extent.

I was aware of the fact that at about the point VIII (See accompanying Map A) selected by me for locating the main intake on the San Joaquin River (consisting of steam or electrically driven centrifugal pumps, lifting the water from the river into a series of extensive settling basins at an elevation of between 50 and 60 feet only, above tide) that the river carried the outflow or runoff from over 5,000 square miles of Sierra Nevada watershed, the main tributary snow water feeders of which are the San Joaquin, the Merced, the Tuolumne and the Stanislaus Rivers, all known for the large amount of water passing annually from the snow covered portions of their respective watersheds.

The location (VIII on map) which I made for the main intake station on the San Joaquin, being just below the points where the Tuolumne and Stanislaus Rivers join the former, gave great assurance of an ample water supply during the snow melting season, as the great abundance of runoff water from these four main feeders would always be a safeguard against a short supply at the point of intake.

Before proceeding with a description of the proposed method of developing the San Joaquin Branch of the system and also before touching on the proposed preliminary development of the Alameda System, and its ultimate development in connection with the San Joaquin River as a feeder, I shall quote from the records of the United States Senate Land Committee, before which, on February 12, 1909, I briefly referred to the San Joaquin River as the nearest additional large source of water supply to be connected with the present and proposed works of the Spring Valley Water Company.

I shall here quote from Page 70 et seq. of the official record of this meeting in Washington in 1909:

> "Hetch Hetchy Reservoir Site. Hearing before the Committee on Public Lands, United States Senate, on the Joint Resolution (S. R. 123) to allow the City and County of San Francisco to exchange lands for reservoir sites in Lake Eleanor and Hetch Hetchy Valley, in Yosemite National Park, and for other purposes."
>
> Question by:—Senator Smoot: Is the Sacramento River feasible?
>
> Answer by:—Mr. Schussler: Yes, but it would be very expensive. You would have to go a long way. But there is one source probably as good as any, except that the quality has been doubted, and that is the San Joaquin River. Now, the San Joaquin River lies right to the west* of part of our headwaters on the Alameda Creek System. I discouraged our directors years ago not to make any investment whatsoever in the Sierra Nevada, because it was too expensive, and because we could get all the water for many decades nearer home; but I have said to them: If you want to increase your water supply over and above the capacity that we can develop the works, which with the coast

*Misprint, should be **East**.

streams on the Pacific Coast is somewhere in the neighborhood of 135,000,000 gallons a day,—

Senator Smoot: That is the San Joaquin?

Senator Fulton: No; he says that they could develop from what they have.

Mr. Schussler: I have told them that if they wanted to go far beyond that, then they could go to the San Joaquin River, across the range, not far from our easterly boundary, and do just the same that the city proposes to do—pump the water over Livermore Pass and run it onto the Company's filter bed that we have—1300 acres of deep gravel beds, where we now filter our water.*

Senator Smoot: Out of the San Joaquin, how much could you develop?

Mr. Schussler: One hundred and fifty million to 200,000,000 gallons a day.

Senator Newlands: Would that be less expensive?

Mr. Schussler: Very much less; but nobody could handle that comfortably unless they had the big filtration works that we have.

Senator Newlands: Are those filtration works natural or artificial?

Mr. Schussler: Natural filtration works. We simply ran a tunnel underneath this prehisitoric lake bottom, which is filled with gravel, and which tunnel we have lined with concrete, and put in a good many thousand 1½-inch galvanized pipes, and through this tunnel we draw now† 14,000,000 gallons a day, which we can increase easily to 80,000,000 or 90,000,000 gallons a day.

Senator Newlands: And the filterbed would be adequate to all requirements for the future?

Mr. Schussler: We can filter 150,000,000 to 200,000,000 gallons daily."§

*The Sunol Filterbeds.
†Early in 1909.

As will be seen from the above quotation, when on the subject of filtering the San Joaquin water I alluded solely to the proposed enlargement of the filtering capacity of *the present Sunol filterbeds,* in order not to draw undue attention to the proposed extensive additional use of the San Joaquin water in the gravel beds and sinks of the Arroyo Mocho and Arroyo Valle, in Livermore Valley, which sinks are tributary to the Company's artesian belt near Pleasanton, in the westerly portion of Livermore Valley, and especially to the land-holdings on and over this artesian belt, to which the Spring Valley Water Company, since the above mentioned meeting of the Senate Land Committee, on February 12, 1909, has added many thousands of acres of artesian and other water-bearing land.

For the purpose of a clear understanding of the proposed additions to the unit-sytem of the combined Peninsular and Alameda Creek Works, I refer to the map (A), herewith, which, together with its many notes in the "Legend", will give an outline of the manner of interlacing and interconnecting of the present and future works on the Alameda branches of the Company's System, with the proposed feeder from the San Joaquin above alluded to.

§(Through the Sunol Filterbed System, when properly enlarged and extended southwesterly and provided with a sufficient number of lateral branch galleries similar to the present ones.)

THE FUTURE COMBINED SYSTEM BEING COMPOSED OF THE PENINSULAR, THE ALAMEDA CREEK AND THE SAN JOAQUIN RIVER SYSTEMS.

A—The Peninsular Division.

My former reports and testimony, as well as my affidavit of June 20th, 1908, gave a large amount of information on the subject of the Company's Peninsular Works and their present and future supply capacity. I shall therefoie not go into details and shall simply state that more than four decades of actual use in the supplying of water to San Francisco has demonstrated that the *net average water-product,* over and above evaporation, from the three storage reservoirs in San Mateo County, viz.: Pilarcitos, San Andreas and Crystal Springs, is fully 18,000,000 gallons per day, and during two consecutive decades was fully 19,500,000 gallons per day, but in all my estimates on this subject I have heretofore placed it at the conservative figure of only 18,000,000 gallons per day.

The above average daily supply of 19.50 million gallons per day is derived from the runoff from the combined watershed of these three Peninsular Reservoirs of about 36 square miles.

This average net water product of fully 19.50 million gallons per day, when divided by the 36 square miles of tributary watershed, shows an average daily net product over and above evaporation of fully 543,000 gallons per day for each square mile of tributary watershed.

The above result could have never been obtained if it had not been for the three above Peninsular storage reservoirs, of a present total capacity of nearly 30,000 million gallons, which are so located in reference to each other and are so thoroughly interconnected with each other, that the overflow from the upper smaller one, Pilarcitos Reservoir, discharges into the San Andreas, or the Crystal Springs Reservoir, or into both, and that also the overflow from the San Andreas Reservoir runs into the large Crystal Springs Reservoir.

Owing to the uncompleted condition of the Crystal Spring Reservoir, water has had to be wasted at times, and may have to be wasted again during heavy winters. I have heretofore placed the average net water yield of the three above reservoirs, with their tributary watersheds, at only 18,000,000 gallons per day, although, with the proposed completion of the Crystal Springs Reservoir, there is no doubt that waste therefrom can be practically eliminated, and the average net water yield from the above Peninsular portion of the Spring Valley Water Company's system can then be safely placed at 19,000,000 gallons per day instead.

A further important feature in the above net supply-result from this combination of three reservoirs, in obtaining the average supply of about 18 million gallons per day from the same, has been the fact of our judicious withdrawal from the gross storage of water required in San Francisco.

If it had not been for such carefully regulated and proportioned average daily supply, so withdrawn from the accumulated storage, the reservoirs would have become overfilled and the result would have been large waste from the reservoirs and thus the above average net yield of about 18 million gallons per day could not have been obtained.

In order to emphasize (under and with our extremely variable climatic conditions and runoff results), the necessity of providing large and abundant storage facilities for the run-off water from the combined watersheds, and also of providing a most perfect, effective and ample system of conduit-intercommunication between the various storage reservoirs of the system (by both of which measures the waste of water from the reservoirs can be reduced to a minimum), I here give the following table from our records of the three reservoirs on the Peninsular branch of the company's system:

TABLE OF RAINFALL AND PERCENTAGE, WHICH THE RUN-OFF CAUGHT BEARS TO TOTAL PRECIPITATION ON THE TWO MAIN DIVISIONS OF THE PENINSULAR PORTION OF THE SPRING VALLEY WATER CO.'S SYSTEM, ALSO GIVING THE ACTUAL QUANTITY OBTAINED FROM THE ENTIRE WATERSHED OF ABOUT 36 SQUARE MILES, DURING 21 CONSECUTIVE SEASONS. (From June 1st to June 1st.)

SPRING VALLEY WATER COMPANY'S PENINSULAR RESERVOIRS AND WATERSHEDS.

	PILARCITOS-SAN ANDREAS COMBINED GROUP Tributary Watershed, 12½ sq. miles from 1889-90 to 1898-99 Tributary Watershed, 13.7 sq. miles from 1899-00 to 1909-10			CRYSTAL SPRINGS GROUP Watershed From 1889-90 to 1898-99 = 23½ sq. miles 1899-00 to 1909-10 = 22½ sq. miles			
Season	Average seasonal rainfall on combined Pilarcitos and San Andreas watersheds (in inches)	Water gained or net run-off equals following percentage of total precipitation	Total net water supply obtained during season from tributary watershed Mill. Gals.	Seasonal rainfall on Crystal Springs watershed (in inches)	Water gained or net run-off equals following % of total precipitation	Total water gained from Crystal Springs watershed	Total gain from entire tributary watersheds of about 36 square miles (million gallons) from seasons June 1st to June 1st
1889-90	73.67	44.7	7,159	72.68	53.20	15,786	22,945
1890-91	37.69	22.8	1,869	31.92	24.4	3,183	5,052
1891-92	43.10	13.3	1,249	24.16	8.0	780	2,029
1892-93	58.25	24.4	3,091	47.07	34.3	6,598	9,689
1893-94	54.90	21.8	2,604	33.08	29.9	4,045	6,649
1894-95	66.93	25.2	3,668	47.69	39.6	7,722	11,390
1895-96	49.45	21.0	2,261	32.62	16.2	2,164	4,425
1896-97	50.47	34.	3,736	35.65	19.3	2,809	6,545
1897-98	26.26	9.6	548	18.17	0.0	(lost) 1,490	942
1898-99	42.56	17.7	1,635	30.37	(lost by evap. 1490) 11.5	+1,427	3,062
1899-00	44.72	37.0	3,937	28.99	16.0	1,812	5,749
1900-01	43.91	30.0	3,138	32.96	7.0	981	4,119
1901-02	40.68	33.3	3,226	30.46	6.9	823	4,049
1902-03	38.00	49.3	4,460	30.80	20.5	2,469	6,929
1903-04	48.63	46.6	5,399	36.98	35.3	5,108	10,507
1904-05	44.80	37.50	3,995	36.51	15.8	2,261	6,256
1905-06	38.51	36.4	3,336	35.58	24.1	3,356	6,692
1906-07	42.65	65.0	6,604	42.58	37.4	6,226	12,830
1907-08	28.72	36.36	2,487	26.22	10.75	1,902	4,389
1908-09	52.27	49.36	6,144	45.86	40.12	7,185	13,329
1909-10	33.49	37.87	3,020	27.93	12.15	1,327	4,347
	Totals		73,566 M. G. or	Totals		76,474 M. G. or	150,040 M. G. or
	A daily average of...		9,595,000 Gal.	A daily average of..		9,975,000 Gal.	19,570,000 Gal.

This table shows the great variation of the seasonal rainfalls and the excessive and most erratic variability of the percentage which the actual net run-off from a watershed bears to the quantity of water that fell as rain during the respective rainy seasons.

This excessive variation in the net percentage caught even between two or more seasons of practically equal rainfall, shows the great difficulty in prognosticating run-off data from watershed and rainfall data alone.

If on the other hand run-off data of reliable character are available for a fairly long period of seasons, then with the aid of rainfall data and a thorough knowledge of the varying characteristics of the watershed, it is possible to approximately subdivide and proportion the total run-off into the separate run-off contributions, that each of the several main branches of the gross watershed may be expected to furnish.

Great Variability in Percentage of Seasonal Run-off.

In examining the above Peninsular Rainfall and Run-off Table it will be found that it would have been impossible for anybody, unless acquainted with the characteristics and habits of the separate streams in the various subdivisions of the watersheds, to determine from a list of former rainfall records alone as to what would have been in the past, or might be in the future, the net run-off from the watershed, due to any year's rain record, or what would be the average annual run-off for a series of years, of which period rain-records only are in evidence, but no run-off records.

The following table, which quotes several years of seasonal rainfall that closely resemble each other from the foregoing Peninsular run-off table, shows the great variation of the percentage of run-off and net quantity of water produced from the combined watershed tributary to Pilarcitos and San Andreas reservoirs:

A—PILARCITOS AND SAN ANDREAS COMBINED.

Season—	Seasonal Rainfall. (in inches.)	Run-off in Percents of total Precipitation.	Net run-off from Watershed (in M. G.)
1890-91	37.69	22.8	1,869
1902-03	38.00	49.3	4,460
1905-06	38.51	36.4	3,336
1891-92	43.10	13.3	1,249
1898-99	42.56	17.7	1,635
1900-01	43.91	30.00	3,138
1906-07	42.65	65.0	6,604
1893-94	54.90	21.8	2,604
1908-09	52.27	49.36	6,144

The following table shows a still more erratic variation in the percentage of seasonal quantity of run-off from the Crystal Springs watershed. In this table, as in the other one, several years of similar seasonal rainfall are grouped together:

B—CRYSTAL SPRINGS RESERVOIR.

Season—	Seasonal Rainfall. (in inches.)	Run-off in Percents of total Precipitation.	Net run-off from Watershed (in M. G.)
1890-91	31.92	24.4	3,183
1895-96	32.62	16.2	2,164
1898-99	30.37	11.5	1,427
1900-01	32.96	7.0	981
1901-02	30.46	6.9	823
1902-03	30.80	20.5	2,469
1893-94	33.08	29.9	4,045
1896-97	35.65	19.3	2,809
1903-04	36.98	35.3	5,109
1904-05	36.51	15.8	2,261
1905-06	35.58	24.1	3,356

The above tables A and B show that even in an ideal watershed regarding location, topography, rainfall, etc., as that of the Company's Peninsular division and with practically equal seasonal rainfalls grouped together, the percentage of run-off in the different seasons of a group varies in some instances in the proportion of more than one to three.

These tables are very instructive, in that they not only give the practical net run-off results for a long series of years from a region of good rainfall, precipitous and wooded watershed and provided with good reservoir facilities, but also show that although rainfall, watershed and reservoir conditions are very favorable, still the run-off conditions are excessively variable.

As prior to actively entering upon the Alameda project our Company had become generally familiar with the fact that rainfall conditions there as well as the erratic action of many of the streams indicated a still greater variability than on the Peninsula in the prospective run-off result, it entered upon the new enterprise with its eyes open, but fully convinced that, although not expecting a yield like the average net result of its Peninsular works of fully half a million gallons per day per square mile of watershed, the extensive properties planned for the Alameda System could by proper works be made to yield per day per square mile of watershed between 30 and 50 per cent of the average daily yield per square mile of its Peninsular watershed and works.

Average Daily Net Run-off from Peninsular System.

During the first decades of the Company's existence the net run-off from the Peninsular watershed, including Crystal Springs, had been placed in round figures at fully 500,000 gallons per day per square mile of watershed.

The above Peninsular run-off tables show the total average daily net product of the entire watershed of about 36 square miles for the above 21-year period as tabulated to have been

$$\frac{19.57}{36} = 543{,}000 \text{ gallons per day per square mile of watershed.}$$

It furthermore shows that the average net run-off from the Crystal Springs watershed alone of an average area (during the above period) of about 23 square miles was:

$$\frac{9.97}{23} = 433{,}000 \text{ gallons per day per square mile of watershed.}$$

The table finally shows that the average net run-off from the combined Pilarcitos-San Andreas watersheds of an area varying during this period from 12.50 to 13.70 square miles, or averaging, say, 13.10 square miles, was

$$\frac{9.59}{13.1} = 732{,}000 \text{ gallons per day per square mile of watershed.}$$

It was next to impossible to keep a separate run-off record between the water products of Pilarcitos and San Andreas Reservoirs, but from observation in the past, and considering the heavier rainfall on the higher, steeper, better wooded and less absorptive Pilarcitos portion of the combined Pilarcitos-San Andreas watershed, it was evident that the net average product from the former, per square mile of watershed per day, was fully double that of the latter.

As the direct watershed tributary to the Pilarcitos Reservoir, including say 50% of the watershed tributary to the side-flume, represents about 4.7 square miles out of the average area of about 13.1 square miles tributary to both reservoirs combined (during the above period shown in the table), it will not be very far from the fact to estimate that the 4.7 Pilarcitos square miles contributed about 1,100,000 gallons per day per square mile, or an average total of about 5,170,000 gallons per day, while the remaining 8.4 square miles of watershed (tributary to San Andreas Reservoir) probably contributed at the rate of about 525,000 gallons per day per square mile of watershed, or at an average of about 4,410,000 gallons per day.

By adding together these two average net daily contributions from the Pilarcitos and San Andreas regions we have from Pilarcitos 5,170,000 gallons per day and from San Andreas 4,410,000 gallons per day, making a total of 9,580,000 gallons per day, which result is very close to the average net water yield derived from the above run-off table of 9,595,000 gallons per day from the combined watershed of Pilarcitos and San Andres of a total average area during the above 21-year period of about 13.10 square miles.

The following is a recapitulation of the above run-off results from the three separate divisions, as well as from the gross area of the entire Peninsular watershed of about 36 square miles:

	Approximate area of watershed (in Square Miles.)	Average daily net water yield (Round Figures.)	Average daily net water yield per square mile of watershed.
From—			
Pilarcitos	4.7	5,170,000	1,100,000
San Andreas	8.4	4,410,000	525,000
Crystal Springs..	23.	9,970,000	433,000
From entire watershed of the three above reservoirs combined......	36.1	19,550,000*	543,000

This shows that where the average daily net product from the entire combined watershed of 36 square miles is about 543,000 gallons per day per square mile of watershed, the Pilarcitos region, which is most favorably situated from a geographical, topographical and hydrographical point of view, produces a water yield per square mile of watershed of about 1,100,000 gallons per day, or fully double the average product over the entire watershed; the San Andreas division, which comes next in regard to favorable location, produces about 96.50% of the average daily product of the entire watershed; and finally, the Crystal Springs division, which is the least favored portion from the three above viewpoints, produces about 80% of the above average net yield of 543,000 gallons per day per square mile from the entire tributary Peninsular watershed of about 36 square miles.

The observations and experiences of the past, although not as fully crystallized then as they are at the present time (owing to shorter periods of observation and to greater scarcity of data), were still of inestimable value to the Spring Valley Water Works and its successor the Spring Valley Water Company in accumulating knowledge and ripening its judgment, so as to properly guide them in making remarkably accurate forecasts in the now distant past, as to the probable net water yield that might and could be expected from properties that were largely in the natural path of future water development for the Company as well as for the City of San Francisco.

The two most prominent water producing properties which owing to their comparative proximity to the Company's Peninsular basis of its water works naturally received the first attention, were the coast streams on the Pacific slope of the Peninsula on the one hand and the magnificent Alameda Creek System on the east side of the bay on the other.

The coast streams are separated from the Company's Peninsular Reservoir System, as then proposed and since inaugurated, by the Coast Range only, but as the points from which the water of the two main coast streams, the Pescadero and San Gregorio Creeks, were to be taken, were found to be of sufficient elevation to carry a large portion of the storm waters of these streams into the Crystal Springs Reservoir, steps were taken by the Spring Valley Water Works, and thereafter by its successor, the Spring Valley Water Company, to secure property at strategical points on one and water rights on both of the streams.

*Above main run-off table shows 19,570,000 gallons per day (see page 98), which difference results from not having rounded off the figures in that table.

Inauguration of the Alameda Creek System.

Studies, observations, computations and occasional preliminary surveys regarding both these important future sources for the city's supply, viz.: the coast streams and the Alameda Creek System, were inaugurated by me in the late fall of 1865, and were carried on with more or less interruptions until about the year 1875, when, after and upon my urgent repeated advice to the Company during the previous decade, it was decided to acquire a substantial foothold on the Alameda System first, leaving the coast streams for some future day.

During 1875 the Water Company acquired the key to the hydrographic situation on the Alameda Creek System by purchasing extensive water rights on the same, as well as property at the mouth of Niles Canyon and at the proposed Calaveras Dam and Reservoir site; the former, the Vallejo Mills water right being one of the oldest rights in California and the key to the Alameda Creek system. The great importance of acquiring and maintaining the integrity of this strategic point cannot be overestimated.

Subsequently more water rights and properties were purchased on the latter system, enabling the Company, during 1887 and 1888, to construct its original Alameda Creek works.

Thereafter, and particularly during the last years of the past century and the first years of the present one, large additional properties and rights were acquired by the Company and the water yield from the system was considerably enlarged by constructing new works, particularly designed for the development on its properties and transportation to San Francisco of subterranean water.

In the latter part of the decade just past and up to the present time the Company has still further added to its extensive holdings on the Alameda System, based upon thorough hydrographic and other studies and has also made additions to its water rights there. It also, by the construction of works, has increased the water output from its subterranean sources on the Alameda System, from about 14,000.000 gallons per day in or about 1908, to nearly 17,000,000 gallons per day in 1909-10 and thereafter.

It goes without saying that during this long period, dating from the first inception of the Alameda Creek plan in 1865, until the present time, and particularly since the first important foothold was acquired by the Company on the Alameda Creek, in 1875, I devoted a great amount of study to that system in order to ascertain not only the possibilities of surface water storage, but also for the proposed development of the subterranean sources that were strongly in evidence in portions of this system.

The main object of these studies, observations and computations was to ascertain what might be the ultimate practical development that this magnificent system, if properly owned and controlled, could be expected to yield, if brought into intimate connection with the Company's Peninsular System, as proposed.

I have here gone into a portion of the past history of the present Alameda Creek System in order to show that when the time had come, about the middle of the eighties (in the past century), that, owing to the City's rapidly growing consumption, it had become imperative that not only must the main Crystal Springs Reservoir be started at once so as to add to the Company's Peninsular supply, by stopping the waste from the Peninsular watershed, but also must the water supply be increased by connecting with these reservoirs additional outside sources as direct or indirect feeders.

As before stated, the two main sources of consequence that offered themselves were the coast streams, Pescadero and San Gregorio, on the one hand and the Alameda Creek System on the other.

The Company Decides to Develop Alameda Creek System Prior to Coast Systems.

Upon being asked by the Board of Directors of the Company which one of the two sources in my opinion could be connected with our Peninsular Reservoir System in the shortest space of time, I naturally decided in favor of the Alameda System, as the construction of the long tunnel through the Coast Range, and of other works, would consume a number of years and make the much-needed help come too late, while, on the other hand, on the Alameda System, the main strategic keys, including water rights, had been purchased fully ten

years previously; and secondly and mainly, as my studies of this magnificent system for the then past period of over twent consecutive years had full yimpressed the Company, not only with the vast development possibilities of the Alameda System proper, but also with the absolute and positive conviction that if or whenever in the then far distant future the proposed future unit system of the Company, consisting of the Peninsular and Alameda divisions combined with the coast streams, should require enlargement of its resources in order to increase, equalize, compensate and safeguard San Francisco's growing water supply, that the Alameda System would form the only and absolutely necessary conecting link between the Peninsular division and such future additional feeders as would be brought from the well-watered region immediately east of Livermore Pass.

The present unique position of the Spring Valley Water Company on the Alameda Creek System is the outcome of the wise and prompt action of the Company's Directors at that time and ever since in inaugurating the construction of the Alameda System at that time (now about a quarter of a century ago) and in continuing, ever since and until this day, to extend its now vast holdings of land and rights on this system, as well as the works thereon.

After this digression, I shall now return to the question of the coast streams, considered as future feeders to the Peninsular portion of the Company's works.

THE COAST STREAMS.

Considered as Future Feeders to the Crystal Springs Reservoir, and Thereby Becoming a Subdivision of the Future Water Supply System of San Francisco.

The original plan for developing the southerly group of coast streams, viz.: the Pescadero and San Gregorio Creeks, so as to act as gravitation feeders to the Crystal Springs Reservoir, included a proposed reservoir in the valley of the San Francisquito Creek, located between the Coast Range and the bay.

The construction of this reservoir was begun and the dam was partly finished to a height of about sixty feet, thus complying with a clause in a contract for the principal water rights requisite on the latter creek.

This partly finished structure was named the "Portola Reservoir."

Subsequently, for a number of reasons, I have again taken up a former plan of mine, which proposed a combination of gravitation, storage and pumping, for the purpose of increasing the water output which would have been obtainable from the two coast streams, by the adoption of the original gravitation plan mentioned above.

Although various reports on the coast streams made from time to time by engineers in the employ of the City practically admitted that the ownership of the Crystal Springs Reservoir controlled the future proper development of the Pescadero and San Gregorio creeks on account of the absence on either of the two creeks of suitable storage reservoir sites, I succeeded, in 1893-4, in finding a first class dam and reservoir site in the valley of the Pescadero Creek at an elevation where the bed of the creek was about one hundred feet above tide.

Col. G. H. Mendell of the United States Engineer Corps, who during 1876-7 was employed by the City authorities to investigate the water situation of San Francisco, states on the subject of these coast streams, in his report of August 6th, 1877, to the Water Committee (consisting of the Mayor, Auditor and District Attorney), on pages 826-827:

> "The rapid fall of the country permits no reservoir site of any value. The storage reservoir must be in the Crystal Springs Valley. We have already seen how prominent a feature the reservoir system is in any discussion of the production and utilization of water. The reservoir sites are the strategic points of the Peninsula, and the Spring Valley Water Company is entrenched upon them. This consideration makes the supply of the western slope, if it is at all considerable, necessarily an adjunct and feeder of the Spring Valley System."

In 1893, when I first discovered this Pescadero storage reservoir site, I contemplated, as I then reported to the Directors of the Company, a storage reservoir of only about 10,000 million gallons capacity.

Subsequent investigations showed me that a masonry dam could be constructed on that site of a much greater height than originally contemplated, so that a dam of a height of about 250 feet above the creek bed would create a res-

ervoir which would hold probably about 25,000 million gallons. This was an approximate estimate, made without the aid of a survey of the site.

The Company, besides purchasing the rocky cliff which will form the northerly abutment of the proposed dam, succeeded during subsequent years in purchasing an almost continuous chain of water rights along both sides of Pescadero Creek and from near the above proposed damsite down to the Pacific Ocean.

The location, from where the Pescadero-Crystal Springs gravitation aqueduct will start on the Pescadero Creek, was purchased as early as 1886-1887, thus establishing the Company at these two important points on the system. Vigorous development of this productive and nearby system may be undertaken at any time.

As the Company, at the time when my report of September, 1903, was written, as well as at the time of my affidavit of June 20th, 1908, owned but a comparatively small portion of its present artesian land holdings in Livermore Valley, I did not include in the above consumption-and-supply diagram of 1908 any additional water that might have been obtained from the extensive subterranean sources in Livermore Valley, but, instead, from and after the year 1935, I show on the diagram that the water supply capacity of the Company's works from and after 1935 are "to be further increased to 110 million gallons daily and over from other Spring Valley Water Company's sources." Chief amongst these proposed "other sources" to be added as direct feeders to the Company's Peninsular System was the contemplated development of the "coast streams," notably the Pescadero and San Gregorio creeks, to fully 50 million gallons per day.

As heretofore shown in the table recapitulating the net water products from the three separate subdivisions of the Company's Peninsular Reservoir System, with its 36 square miles of tributary watershed, the Pilarcitos portion of the same furnishes an average net run-off in round figures of about 1,100,000 gallons per day per square mile of watershed.

The watershed tributary to the proposed coast stream works, if only the gravitation branch from the Pescadero and San Gregorio to Crystal Springs Reservoir were developed, would in round figures be 41 square miles.

If, on the other hand, the proposed large storage reservoir on the down stream portion of the Pescadero is added to the above gravitation scheme as contemplated, the watershed will be increased by about 19 additional square miles, making the total tributary watershed equal to about 60 square miles.

The water, which during severe storms in the rainy season (after filling the gravitation aqueduct leading to Crystal Springs Reservoir) would overflow over the two respective diverting dams on the Pescadero and San Gregorio, would find its way into and would be accumulated in the large proposed storage reservoir on the Pescadero Creek (see map), the overflow water from the latter creek finding its way into the storage reservoir by running along the natural bed of the stream, while the overflow water from the San Gregorio would be conducted into the reservoir by a tunnel, about 1¼ miles in length. (49 on map.)

In the above mentioned table, which gives the rainfall, etc., of the Peninsular works during the seasons from 1889-90 to 1909-10, the average rainfall given in the second column states the combined or average rainfall on the Pilarcitos and San Andreas divisions.

A separate rainfall table for Pilarcitos alone is shown in the table here following, for fifteen consecutive seasons (out of the above 21), while at the same time giving the rainfall record kept on the Pescadero watershed during the same 15-year period:

Season—	Seasonal rainfall at Pilarcitos (in inches).	Seasonal rainfall at Pescadero Creek (in inches).
1889-90	72.09	93.67
1890-91	39.02	46.71
1891-92	52.76	40.76
1892-93	67.00	72.83
1893-94	67.87	49.94
1894-95	76.10	68.94
1895-96	56.34	54.72
1896-97	58.57	63.13
1897-98	31.16	24.35
1898-99	51.48	42.53
1899-00	52.75	47.73
1900-01	52.28	52.20
1901-02	48.54	45.50
1902-03	39.47	48.47
1903-04	56.86	55.88
Average per season	54.80	53.80
	Pilarcitos	Pescadero

Judging from the above rain records and all other conditions combined surrounding the region of these two coast streams, it has been found that they are practically analogous with

the conditions prevailing at Pilarcitos.

As shown in the last rainfall table, the average rainfall conditions during the continuous 15-year period quoted are practically the same on the coast streams as at Pilarcitos, the average seasonal rainfall in the former being 53.80 inches to 54.80 inches in the latter.

The topographical features of the coast stream watersheds are similar to that of Pilarcitos, with the difference that the average steepness of the mountain slopes is greater in the former than in the latter, thus expediting the run-off during storms.

The coast stream watershed is forest-covered to a somewhat greater degree than that of Pilarcitos, especially that on the Pescadero portion.

Stream gagings on the Pescadero Creek at a point where the tributary watershed is about 16 square miles in area, were carried on by the Company with the following results, and as a matter of comparison I shall place alongside of these Pescadero run-off results the net water product gained for the corresponding seasons from the 13.7 square miles of combined Pilarcitos and San Andreas watersheds (see main table):

Season—	Run-off from 16 square miles of Pescadero watershed, (M. G. round figures.)	Net run-off from 13.7 square miles (during this period) of Pilarcitos and San Andreas watersheds combined. (M. G.)
1899-00.........	2,650	3,937
1900-01.........	9,180	3,138
1901-02.........	5,650	3,226
1902-03.........	4,500	4,460
1903-04.........	9,740	5,399
1904-05.........	7,390	3,995
Totals	39,110	24,155
Annual average	6,518	4,025
Daily average	17.85	11.02
Daily product per sq. mile of watershed	1,115,000	804,000

As heretofore shown, the average product per square mile of watershed for a period of 21 years, from the combined watersheds of Pilarcitos and San Andreas, was 732,000 gallons per day. For the above six seasons (shown in last table) the average daily run-off per square mile of Pilarcitos-San Andreas watershed was **804,000** gallons. In other words, the average product per square mile per day of the above 21 seasons is equal to about 91 per cent. of the average water product per square mile per day for the six seasons.

It is therefore fair to presume that the average run-off during the same 21-year period from the above Pescadero watershed would have also been about 9 or 10 per cent. less than it was during the 6-year period from 1899-1900 to 1904-1905.

Ninety per cent. of 1,115,000 per square mile per day would be 1,003,500, or in round figures **1,000,000** gallons per day per square mile of watershed, which will represent the average daily run-off from the watershed of about 60 square miles of Pescadero and San Gregorio combined.

Even allowing a 10 per cent. reduction from this average gross result for loss by occasional waste at San Gregorio and evaporation combined, which latter, owing to the nearness of the ocean and the practical absence of winds from the sheltered main reservoir location, will be comparatively light, we have 900,000 gallons average daily net product per square mile of combined watershed of an area of about 60 square miles.

This represents an average net product, that can be developed on the combined Pescadero and San Gregorio properties under the plans hereinabove outlined, of 54,000,000 gallons per day,* which net daily supply in my estimates I have rounded off to the conservative figure of **50,000,000** gallons per day.

BRIEF OUTLINE OF THE PROPOSED COAST STREAM WORKS.

In order to develop in the coast stream project an average net water supply of fully 50,000,000 gallons per day a concrete lined gravitation aqueduct (shown on accompanying map A by aqueduct numbered 47-46-45-44-43 with arrows pointing northwardly) will be constructed of a capacity of, say, not less than 100 million gallons per day, which aqueduct, except during and for some time after heavy freshets, will transport by gravitation all the run-off from both streams and their tributaries, into the Crystal Springs Reservoir.

The overflow water, that is, the water that

*A gaging station was established on the upper Pescadero Creek in 1886 and stream measurements were made continuously from 1886 until 1906, which were confirmatory of the productivity as herein shown for the "Coast-Stream Division". Unfortunately these records were destroyed in the fire of 1906, except for the six seasons from 1899-1900 to 1904-5.

during and following severe storms cannot be carried away by the aqueduct, will be stored in the main Pescadero Reservoir (XXVI on map) into which the overflow water from the San Gregorio will also be brought (as above stated) by a concrete lined tunnel about 1¼ miles in length (49-49a) having a carrying capacity from the lower diverting dam (49) on the San Gregorio, to and into the Pescadero main storage reservoir, of, say, 100,000,000 gallons per day.

The proposed main Pescadero storage reservoir, as stated above, will be formed by a substantial masonry or rather concrete dam. built in the narrow rocky gorge of the valley, located about six miles above the mouth of the creek.

No special survey has as yet been made of this reservoir and its probable storage capacity.

The United States contour maps of this region, however, which were published a number of years after I made the location of the reservoir in 1893, give a very fair idea of the approximate storage that may be obtained. Approximate estimates made therefrom indicate that for a dam of a height of about 250 feet above the creek-bed a storage capacity of about 25,000 million gallons may probably be obtained.

It is therefore evident that, based upon the United States Geological charts of this region, there is ample storage capacity available in the coast stream project, so that between direct gravitation transportation into the Crystal Springs on the one hand and storage of the overflow freshet waters on the other, coupled with a properly designed and constructed pumping plant (XXVII on map) to deliver, when required, Pescadero storage water (via the pumping conduit, 50-50) into the gravitation aqueduct (45), thus sending towards and into the Crystal Springs enlarged reservoir an average net supply in excess of 50,000,000 gallons per day which can be depended upon from the coast stream division if developed and operated as above outlined.

By adding the above net water product of the proposed coast stream division of fully 50 million gallons per day to that of the original Peninsular Reservoir Division, of fully 19 million gallons per day, which latter comprises the net product of Pilarcitos, San Andreas and Crystal Springs Reservoir combined from the present watershed area of 36 square miles, and being exclusive of the average net product of fully 3 million gallons per day from Lake Merced, we have a total net average product to which the Peninsular Division, including the coast stream division, can be developed of about or in excess of 70 million gallons per day.

The Alameda Creek Division of the Spring Valley Water Company's Supply System.

In the foregoing portion of this report the proposed development of the Alameda Division of the Company's water supply system has been alluded to from time to time and a list of the contemplated storage capacities of the three proposed storage reservoirs in this division, the Calaveras, Arroyo Valle and San Antonio, has been given.

Regarding the question of the water supply that can be developed on the Alameda Creek Division of the Company's System, I stated in my "Review" of January 22d, 1912:

> "In my reports in the past, both oral and written, I have maintained that the average net daily water yield per square mile of watershed of the Alameda System would fall considerably below that of the San Francisco Peninsular watersheds above mentioned; my estimate for the entire Alameda System being about 40% of that of the Company's Peninsular Reservoir System, which difference is due mainly to the lesser rainfall.
>
> "This placed my estimate of the average water yield of the entire watershed of the Alameda System at 40% of 500,000, or at about 200,000 gallons per day per square mile of watershed."

In one of my reports, made to the Board of Directors of the Company in the latter part of the nineties, urging them to continue the acquisition of lands in and around the artesian region of Livermore Valley, as well as of other needed lands and rights in the balance of the Alameda Creek System, I made an approximate rating as to the comparative water yield that the various subdivisions of the proposed Alameda System could be made to furnish by proper grouping, development and works.

The region tributary to the Pleasanton artesian belt, including Arroyo Mocho, but exclusive of Arroyo Valle, I then rated at a daily net water yield of about 100,000 gallons per square

mile of tributary watershed, while the Laguna Creek, Sunol, San Antonio and Arroyo Valle divisions I placed at an average of about 200,000 gallons per day per square mile of watershed. The balance, consisting of the Alameda Creek and Calaveras Division, I rated at about 400,000 gallons per day per square mile of watershed.

In making this approximate estimate I had the benefit of nearly ten years of run-off data taken at the Niles dam, and my general intimate acquaintance of over thirty years with all the vital features of the Alameda System, as to topography, hydrography and general habits of the various streams during and after rainy spells and seasons.

In the same "Review" of January 22d, 1912, quoted above, I showed that the Alameda Creek Division, above Sunol dam, if fully developed and properly utilized, could, in my opinion, be made to produce an average net supply of about 120 million gallons per day, which daily average total was in that report divided into two subdivisions, viz: Forty-six million gallons per day obtained from the Arroyo Valle Reservoir and from subterranean development combined, from a gross watershed then approximately estimated at about 360 square miles tributary to the large gravel sink and artesian belt in Livermore Valley, and the balance of 74 million gallons per day from the combined remainder of Alameda Creek watershed, estimated in that "Review" of January 22d, 1912, at about 270 square miles area.

Since the above "Review" report was written, I have made a new map of the Alameda Creek region, composed partly of geological survey sheets and partly of portions of the respective county maps. By planimeter measurement this map area shows an area of about 620 square miles.

The question whether the watershed area contains 630 or 620 square miles will make no difference in the total average annual or daily run-off result from the combined system when completed. But, as the gross watershed area in this case will be of interest, in order to segregate it into its various subdivisions and in order to proportion as near as practicable the closely known total actual annual run-off from the entire watershed, among the main subdivisions of the same, I have in the following adopted my last result of round 620 square miles as the gross watershed of the Alameda Creek region above Sunol dam.

OUTLINE OF WORKS AND METHOD OF OPERATION OF ALAMEDA CREEK SYSTEM.

In the future operating program for the Alameda Creek Division with its three contemplated reservoirs:

	M. G.
Calaveras, with a storage capacity of.........	53,000
Arroyo Valle, with a storage capacity of......	12,500
San Antonio, with a storage capacity of......	10,500
Or with a total storage capacity of...........	76,000

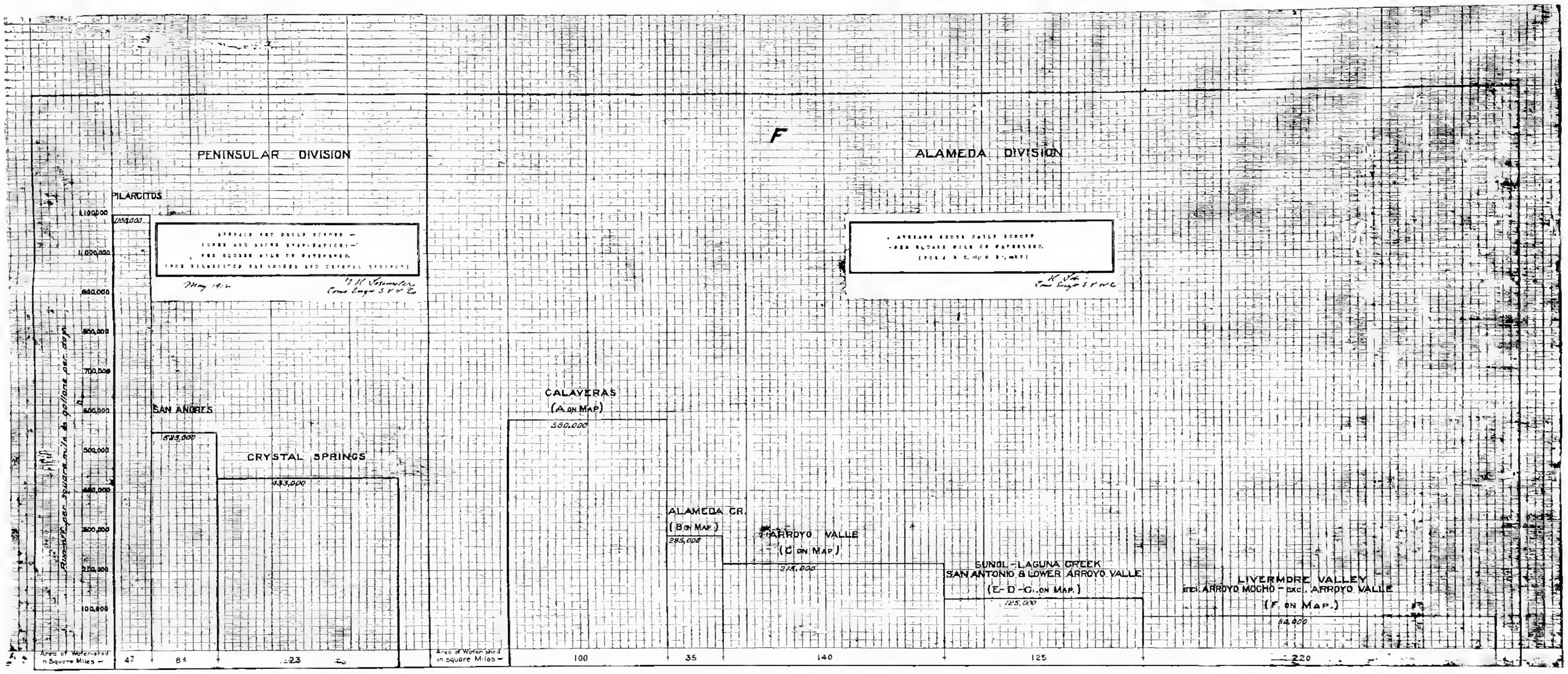
and with its two large subterranean water regions, the smaller one at Sunol acting mainly as compensating and filtering medium, while by far the larger one in Livermore Valley, acts as a compensating, filtering and storage medium combined. These properties and works will be divided into the three following main subdivisions:

(a) The Calaveras Subdivision.

This subdivision will have a combined watershed of 135 square miles, being round 100 square miles for the Calaveras direct watershed, and about 35 square miles for the adjacent feeder, Upper Alameda Creek. The Calaveras reservoir will have a contemplated storage capacity of about 53,000 million gallons.

This reservoir will have a main westerly outlet tunnel (19 on map) of not less than 150 million gallons daily carrying capacity from the westerly outlet of which one and eventually two 60-inch iron pipe lines, if required (18 on map), each of a carrying capacity of about 75 million gallons per day, will deliver the water from the Calaveras storage reservoir through a tunnel (T 18 on map) of a carrying capacity of between 250 and 350 million gallons per day into the Crystal Springs Reservoir.

The second outlet from the Calaveras storage reservoir will be by a tunnel through the westerly bluff and around the westerly end of the proposed Calaveras dam (23 on map), thus allowing water to discharge from the reservoir and run down the Calaveras Creek to and into the gravel sink in the Sunol Valley, which sink has an approximate area of two square miles and from which gravel bed, by means of the present and future largely extended filter gallery system, the waters so liberated from the Calaveras Reservoir, jointly with the waters from other sources, will pass through a thorough, automatic filtering process before con-



HYDROGRAPH SHOWING RUN-OFF PER S]UARE MILE OF CATCHMENT OF PENINSULAR AND ALAMEDA DIVISIONS.

veying it away for purposes of domestic consumption.

The above outlined southerly, or rather southwesterly subdivision of the Alameda branch of the unit-system of the Company, having 135 square miles of watershed tributary to the Calaveras Reservoir of a proposed storage capacity of 53,000 million gallons, I shall hereafter call the CALAVERAS SUBDIVISION, or ALAMEDA SUBDIVISION A.

(b) The Arroyo Valle-San Antonio Subdivision

This subdivision consists of the watershed directly tributary to the proposed Arroyo Valle Reservoir, of about 140 square miles, and of that tributary to the proposed San Antonio Reservoir, of about 40 square miles of watershed, making a total watershed of about 180 square miles for both reservoirs combined.

In other words, where about 140 square miles are directly tributary to the Arroyo Valle Reservoir of a proposed storage capacity of round 12,500 million gallons, and where the San Antonio Reservoir of about 10,500 million gallons storage capacity has a direct watershed of nearly 40 square miles, and where, furthermore, an additional watershed area of fully five square miles in lower Arroyo Valle and just below the reservoir location, can also be made tributary to the Arroyo Valley-San Antonio tunnel (see 41 on map), it appears that the watershed that will be made directly tributary to the San Antonio reservoir from these sources has an area of about 185 square miles.

As above stated, this gross watershed area of about 185 square miles contains the two storage reservoirs of Arroyo Valle and San Antonio, of a joint storage capacity of 23,000 million gallons.

Thus, if at any time the Arroyo Valle Reservoir during a rainy season threatens to become too full and needs relief, the surplus can be sent down stream, via Arroyo Valle Creek and tunnel 41, into the San Antonio Reservoir, thus making up such deficit in the latter's own storage, as may have been caused by insufficient run-off from its own watershed, or by insufficient supply sent into it from other tributary sources.

On the other hand, if at any time it is desirable to either replenish the water in the subterranean gravel beds and in the Company's artesian belt in Livermore Valley, the required supply, instead of diverting it all through tunnel 41 into the San Antonio Reservoir and from there into and through the Sunol filter beds, can be partly or wholly sent down along the porous, gravelly bed of the Arroyo Valle, and from there can be either allowed to sink into the vast porous gravel bed underlying the central and westerly portion of Livermore Valley or can wholly or partly be extracted (as detailed in my former reports, and especially that of November 14th, 1911) by an extensive subterranean filter gallery system (32-32-32 on map), paralleling (and crossing with branch galleries*) the broad, porous, gravelly bed of the Arroyo Valle, and thus be conveyed in a filtered state by gravitation through aqueduct (31-31 on map) directly into "*the meeting place of the waters*" in Sunol Valley (X on map).

Meanwhile, as shown in my former reports and as outlined on the main map accompanying this report, a complete and effective system of artesian wells, suction pipes, pumps (30-30-30 and IV-V-VI) and main conduit lines (31-31 on map) will be constructed on the Company's artesian belt in the westerly portion of Livermore Valley, similar to and in connection with the plant at present in operation on that property. The water so extracted from the large subterranean storage in the extensive gravel beds there, either by the present pumping method or by air lifts, or both, will be delivered into the main aqueduct (31-31-31 on map), which in turn will deliver it by gravitation to and into the main receiving chamber of the Sunol filter beds, at X on map.

This main aqueduct (31-31-31 on map) will be of sufficient carrying capacity to convey to Sunol Valley not only the water extracted from the Pleasanton artesian belt by the well, pipe and pumping system (IV-V-VI 30-30-30 on map) and the waters gathered from the filter beds (32-32-32) of the Arroyo Valle, as well as those of the Arroyo Mocho (32-a), but also to carry to the same destination in Sunol Valley (X on map) the waters that, after having been delivered from the San Joaquin through Livermore Pass tunnel (38-38 on map) into

*See accompanying cross sections of branch and main subterranean filter galleries in the Sunol gravel beds. The extensive filter gallery system in the gravel beds of Arroyo Valle and Mocho, in Livermore Valley, will be of similar construction.

and through the lateral canal (39-39-39) in the easterly portion of Livermore Valley, are allowed to sink (at 39-D on map) into the gravel bed of the Mocho, or, at 39 D-D, into the gravel sink of the Arroyo Valle.

Such portion of the San Joaquin waters therefore as have not been sent ahead through tunnel 41 into the San Antonio Reservoir, and from there into and through the Sunol filter beds via the distributing canal (42-29 on map), but, instead, have been dropped at 39 D and at 39 D-D into the gravel sinks of the Mocho and Arroyo Valle, respectively, and after having passed for several miles subterraneously in a general westerly and northwesterly direction, respectively, through the extensive gravel bed underlying that portion of the Livermore Valley, having been thus thoroughly filtered, will be extracted again from the underground gravel strata by means of and through the filtering galleries, 32-32, on the Arroyo Valle, and 32a on the Mocho.

Such portions of the San Joaquin water as are not thus extracted by either or both galleries, 32-32 and 32a, will, by gravitation, find their way subterraneously in a westward direction, until they join the other waters gathered in the vast Pleasanton artesian belt of the Company, which have there accumulated from their own natural watershed, with or without assistance from the Arroyo Valle Reservoir.

STRATEGIC LOCATION AND IMPORTANCE OF THE LIVERMORE GRAVEL BEDS.

The above brief outline of the eventual development of the present and proposed water resources, which will find their way into and through the Livermore Valley, with its unique automatic filtration and artesian facilities, shows the wonderful versatility of this magnificent property located in the heart or center of gravity of the northerly and northeasterly subdivision of the Company's magnificent Alameda project. What makes the feature of its geographical location all the more valuable is the fact that in addition to gathering, filtering and compensating its own direct water product, it lies, figuratively speaking, within a stone's throw of the point where a kind Providence delivers during spring and summer, from many thousands of square miles of the high, snow-clad Sierra Nevada, a practically inexhaustible supply of good potable water, after passing through rockbound and indestructible natural aqueducts, the canyons of the San Joaquin, Merced, Toulumne and Stanislaus rivers.

By means of the hereinbefore and hereinafter detailed method, all embodied in, and made possible by the proposed development of the Alameda and Peninsular Unit-System of the Company, the waters coming from the melted snow of the Sierra, conducted to our very doors by indestructible, natural aqueducts, can and will be filtered, compensated, conveyed, stored and delivered into San Francisco and its future suburbs, thus taking care of the future needs of its coming millions of inhabitants.

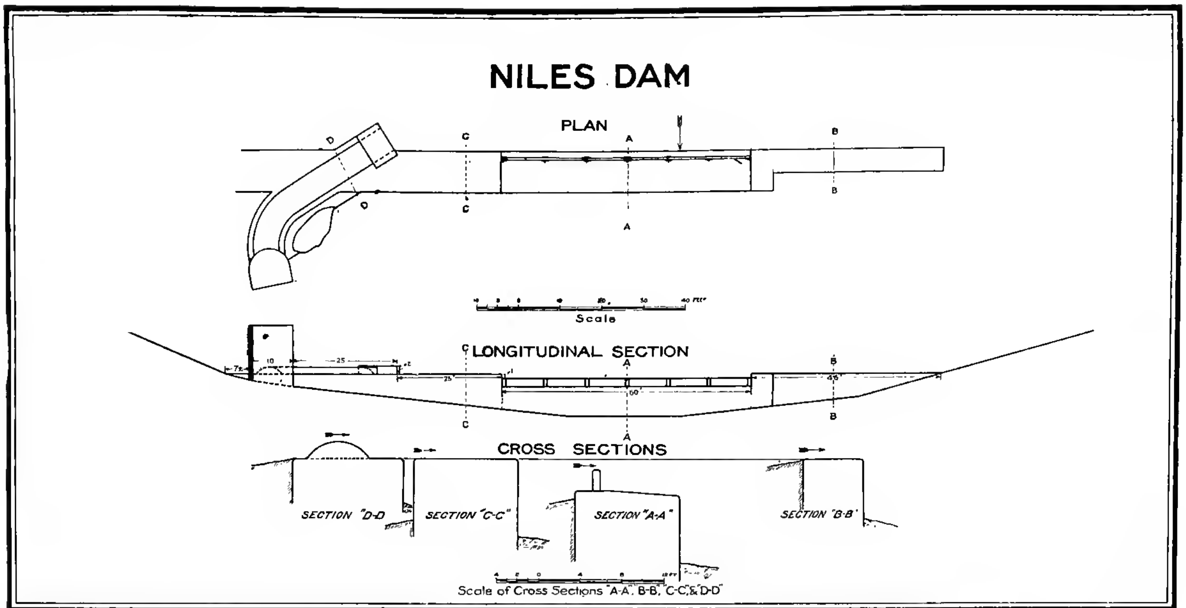
The fact that only by means of the magnificent and large filtering and storage facilities of the Spring Valley Water Company on both sides of the Bay, the vast, but periodical supply of the snow waters of the Sierra Nevada can be utilized, adds an enormous increment to the already great value and utility of the Company's combined properties.

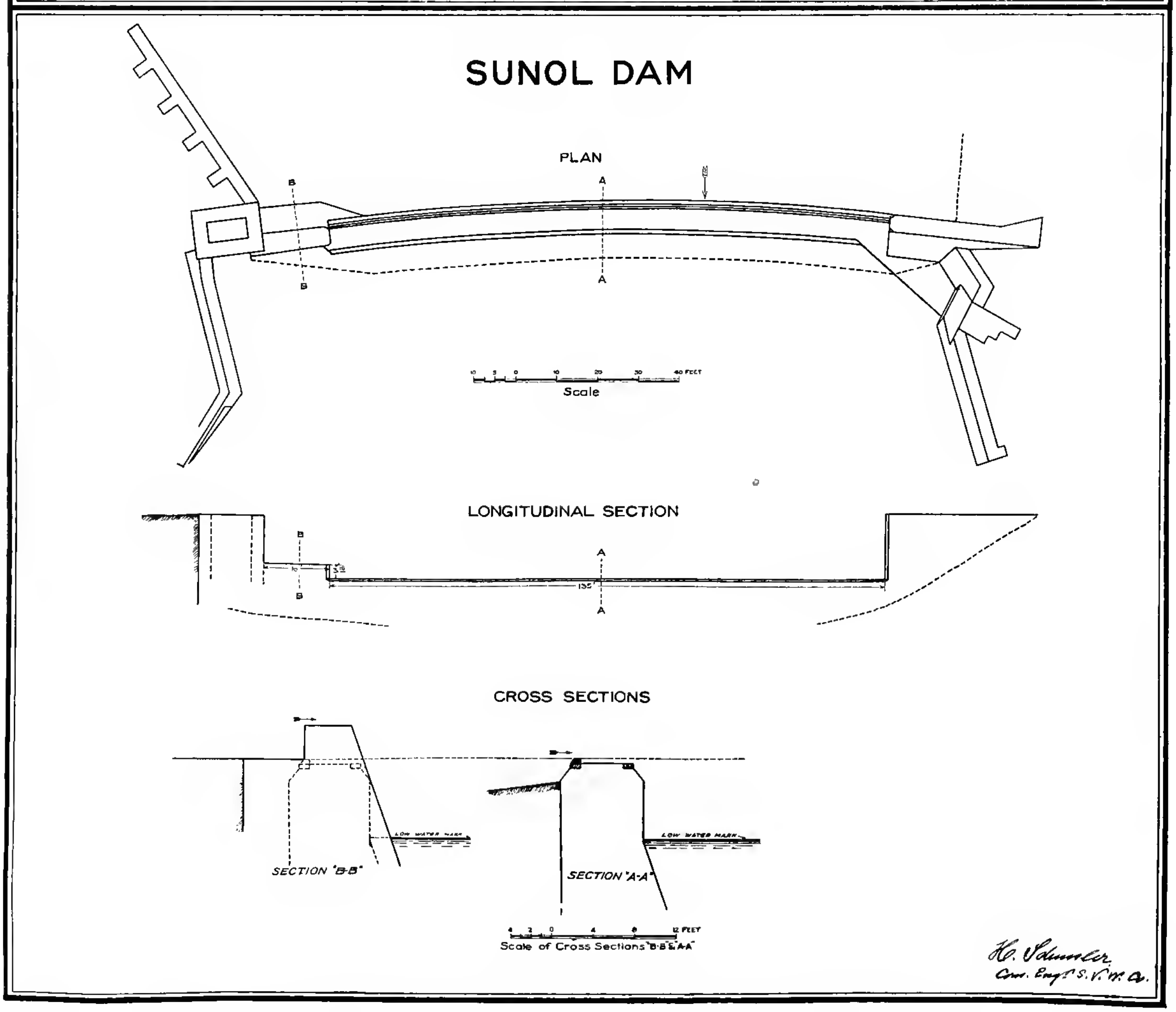
Before describing the plan of connecting the San Joaquin supply with the Alameda Division of the Company's system, I will enter more fully into the extent of the water supply that can be obtained by the full development of the Alameda Division in intimate connection with the Peninsular Division, as well as with such other feeders, as will assist in the maximum development of the water resources appertaining to the Alameda Division proper.

THE WATER RESOURCES OF THE ALAMEDA DIVISION WHEN FULLY DEVELOPED.

By observation, studies and computations, my former conviction has been fully confirmed, that the gross amount of water that has actually passed over both the Niles and the Sunol dams during each year of the 19-year period from 1889-90 to 1907-08, inclusive, is in excess of that shown in the run-off tables used in the Spring Valley Water Company's office.

It has always been the Company's policy never to overestimate the potentiality of its water resources, but, instead, to be very conservative and rather err on the safe side. I therefore advised retaining the same method of computing the run-off as heretofore used with the knowledge that the results so obtained would be very conservative.





PLAN AND SECTIONS OF NILES AND SUNOL DAMS.

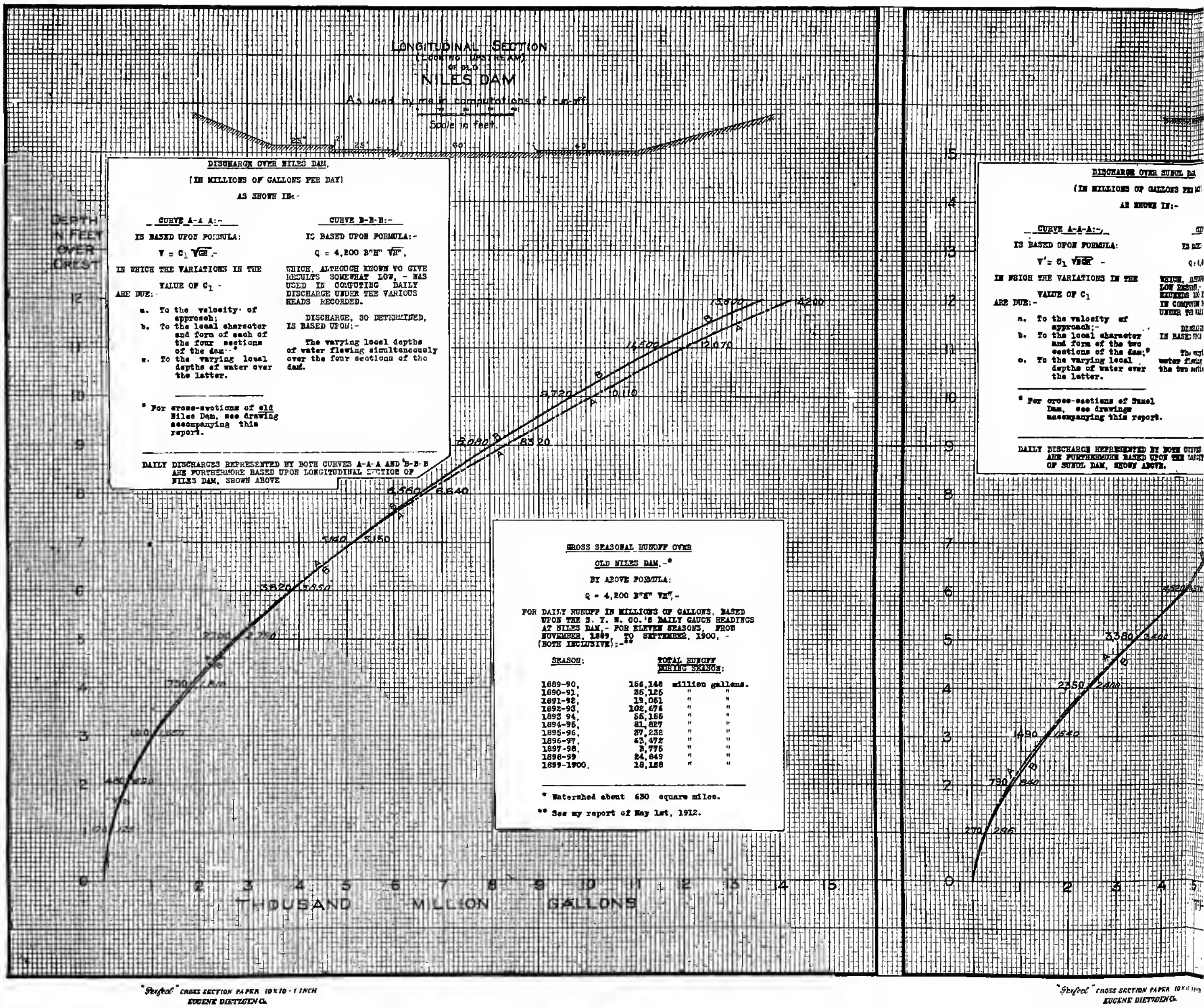
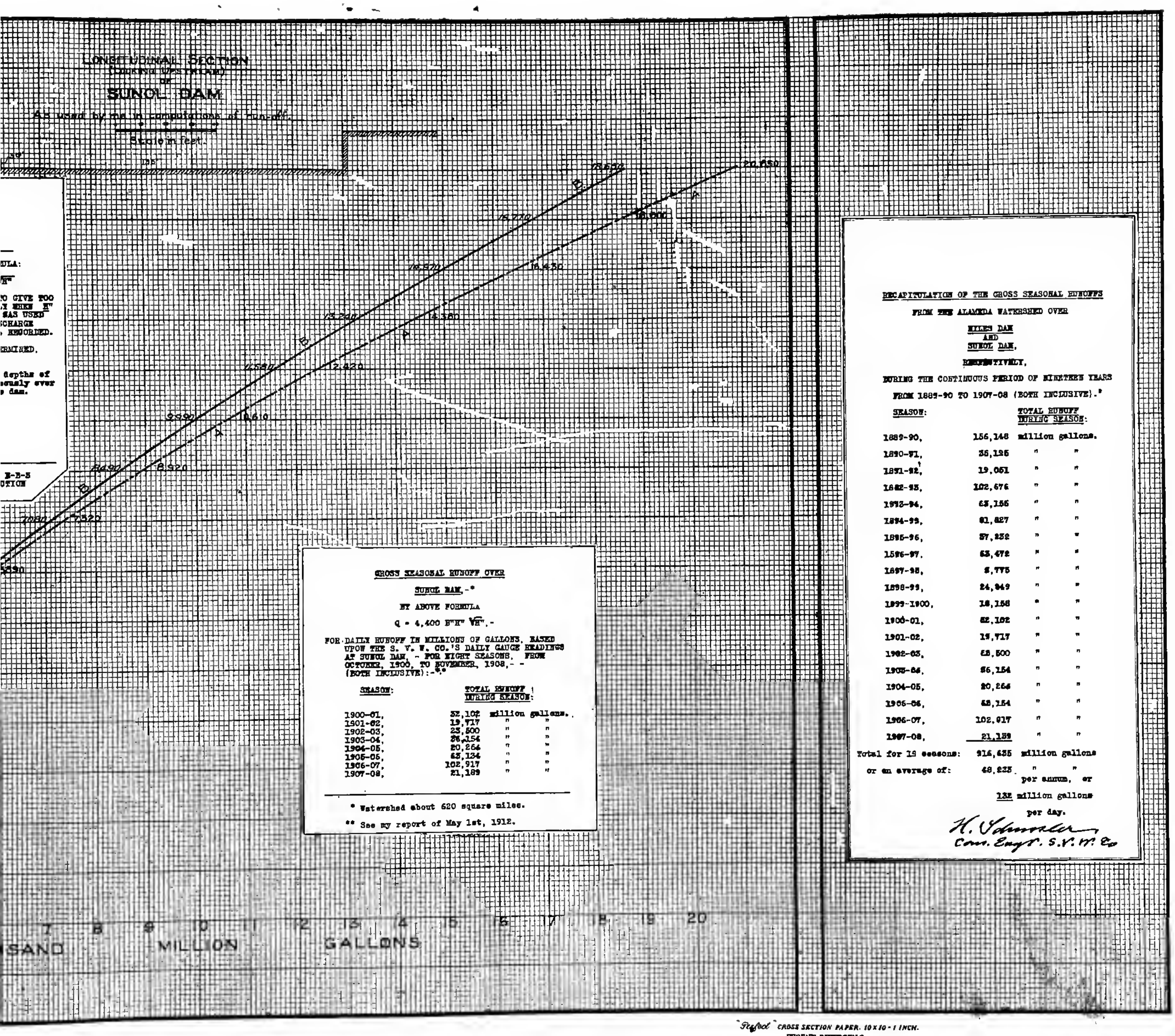


DIAGRAM OF COMPARATIVE DISCHARGE CURVES COMPUTED BY H. SCHUSSLER, SHOWING GROSS SEA



GROSS SEASONAL RUNOFF OVER

SUNOL DAM,-*

BY ABOVE FORMULA

Q = 4,400 B"H" √H".-

FOR DAILY RUNOFF IN MILLIONS OF GALLONS, BASED UPON THE S. V. W. CO.'S DAILY GAUGE READINGS AT SUNOL DAM, - FOR EIGHT SEASONS, FROM OCTOBER, 1900, TO NOVEMBER, 1908,- - (BOTH INCLUSIVE):-**

SEASON:	TOTAL RUNOFF DURING SEASON:	
1900-01,	52,102	million gallons.
1901-02,	19,717	" "
1902-03,	23,500	" "
1903-04,	36,154	" "
1904-05,	20,264	" "
1905-06,	63,134	" "
1906-07,	102,917	" "
1907-08,	21,189	" "

* Watershed about 620 square miles.

** See my report of May 1st, 1912.

RECAPITULATION OF THE GROSS SEASONAL RUNOFFS

FROM THE ALAMEDA WATERSHED OVER

NILES DAM
AND
SUNOL DAM,

RESPECTIVELY,

DURING THE CONTINUOUS PERIOD OF NINETEEN YEARS

FROM 1889-90 TO 1907-08 (BOTH INCLUSIVE).*

SEASON:	TOTAL RUNOFF DURING SEASON:	
1889-90,	156,148	million gallons.
1890-91,	35,135	" "
1891-92,	19,061	" "
1892-93,	102,676	" "
1893-94,	63,156	" "
1894-95,	81,827	" "
1895-96,	57,252	" "
1896-97,	63,472	" "
1897-98,	8,775	" "
1898-99,	24,949	" "
1899-1900,	18,158	" "
1900-01,	52,102	" "
1901-02,	19,717	" "
1902-03,	23,500	" "
1903-04,	36,154	" "
1904-05,	20,264	" "
1905-06,	63,134	" "
1906-07,	102,917	" "
1907-08,	21,189	" "
Total for 19 seasons:	916,635	million gallons
or an average of:	48,235	" " per annum, or
		132 million gallons per day.

H. Schussler
Cons. Engr. S.V.W. Co

NAL RUN-OFF OF ALAMEDA CREEK OVER NILES AND SUNOL DAMS FROM 1889-90 TO 1907-08.

The Niles dam was built for the purpose of holding the original General Vallejo location of intake to the former mill race, and, secondly, to divert the water of the creek into the "Niles aqueduct" of the Spring Valley Water Works.

The dam was not built with the view of acting as a weir for the purpose of measuring the water flowing over it. I know from personal observation that this low diverting dam (being built no higher than necessary in order to divert the water from the creek into the comparatively small "Niles aqueduct"), would, during flood seasons on the creek, be so overwhelmed by the large volume of water rushing with great velocity down the steep Niles Canyon, that it would only be noticed during high water by a comparatively small parabolic drop, thus apparently disposing of any attempt to ascertain the quantity of water by so-called "weir measurements."

The main idea at that time was to record the depth of the water in the stream and to approximately, but conservatively, determine the average annual or daily gross water yield of the entire system.

From my many years of experience, I fully realized that, once having the gross annual run-off from the entire system, it would be easy, by the aid of rain and local run-off records, to ascertain the average water yield from the various subdivisions of the system.

After making several series of current observations during the years subsequent to the first diversion by our Company of the Alameda Creek water, at the same time watching the action of the water as it passed over the Niles dam, I found that a very close approximation to the actual quantity in the stream could be had by using a simple and compact formula of mine.

Although both dams (Niles and Sunol) during high freshets act practically as submerged weirs, in that the water below the dam at times backs over the crest of the same to a height amounting to from 60 to 80 per cent of the total depth of water above the dam, still the velocity with which the torrent approaches the dam is so great as it jumps with a flattened parabolic curve over the dam and into the tail-water below the same, that it plunges through the latter, down to the very bottom of the creek bed.

The increased velocity and general action of the stream is further facilitated by the fact that especially during the higher stages of water, the cross-section of the stream where it passes over the dam is somewhat smaller than that of the stream approaching it. It is also aided by the fact that gravel and other debris (carried with the freshets over the dam) have rounded off and smoothed the top of the low timber bulkhead and that on account of the comparatively small amount of end-contraction in the overfall, friction is reduced and the velocity increased.

Thus, the combination of the conditions surrounding *Niles dam,* and the water passing over the same, allows the great velocity of approach to overcome the frictional resistance. The otherwise retarding effect of the flat surface on top of portions of the same, are more than offset by the velocity of approach.

All of which contributes to make the run-off results as heretofore computed by the Company quite conservative.

A similar condition as to run-off results, as here detailed for the Niles dam, prevails, with some modifications, at the Sunol dam, the main difference being that the top of the latter dam is of a more even structure than the former, and that it is therefore better suited than the Niles dam for obtaining run-off results. Still, during high water the Sunol dam has been known to be submerged by the tail-water from below to fully 80 per cent. of the depth of the water over the dam from above.

The wooden crest had a beveled slope on the upstream side, favoring the overflow of the water and at the north end of the dam a concrete wingwall assists in guiding the water to and over the dam. The up and downstream edges of the main portion of the top of the concrete dam are beveled; all of which favors the flow of water over the same.

With the great velocity of approach, aided by the shape of the dam (favorable to the overflow), the resistance of the back-water on its crest is easily overcome, so that the overflowing stream dives into the water below the dam, clear down to the deep bed of the creek.

Current observations, computations, and studies relative to the quantity of water discharged over the Sunol dam at various depths of the stream as well as innumerable experiments made by me in former decades, with free as well as submerged weirs, flowing both from

still water heads or with velocities of approach, proved to my satisfaction that the formula adopted by me for the Niles dam could also with a slight modification be employed for the Sunol dam, insuring results that could be depended upon as being conservative and well inside of the facts.

The Run-off From the Alameda Creek Division of the Spring Valley Water Company's System

Based upon gagings of the depths of water over the Niles and Sunol dams, respectively, during the 19-year period from 1889-90 to 1907-08 (inclusive), the following table, giving the gross seasonal run-off from November 1st to November 1st of each year, has been constructed. With the exception of a former clerical error in the run-off of 1897-98 (which has heretofore been and is herein corrected) it is the same as given in my "Review" of January 22d, 1912:

GROSS RUN-OFF FROM ALAMEDA WATERSHED.

Season from Nov. 1 to Nov. 1.	Total run-off during season. M. G.
1889-90	156,148
1890-91	35,125
1891-92	19,051
1892-93	102,676
1893-94	55,155
1894-95	81,827
1895-96	37,232
1896-97	63,472
1897-98	3,775
1898-99	24,849
1899-00	18,158
1900-01	32,102
1901-02	19,717
1902-03	23,500
1903-04	36,154
1904-05	20,254
1905-06	63,134
1906-07	102,917
1907-08	21,189
Total for 19 seasons	916,435
Or an average of—	
M. G. per annum	48,233
Or, M. G. per day	132

PROPORTIONING THE ABOVE AVERAGE GROSS RUN-OFF RESULTS AMONGST THE VARIOUS SUBDIVISIONS OF THE ALAMEDA CREEK SYSTEM.

A—Calaveras Run-off.

Run-off records at the Calaveras reservoir site are available for two separate periods, the first series being for the 5-year period from 1898-99 to 1902-03 (inclusive), the results of which from my investigation appear to be very close to the facts. The second period of run-off measurements, cover the four seasons from 1904-05 to 1907-08 (inclusive). Although, during my studies on the subject in the summer of 1911, I accepted them for my computations, I have since come to the belief that, unless revised, their average is perhaps 10 per cent. too high.

In my "Review" report of January 22d, 1912, I say on this subject:

> "The Calaveras stream gagings, * * * which at that time * * * were furnished to me and which I accepted as being accurate, were * * * for the seasons from 1904-5 to 1907-8, inclusive, * * * used by me in my report of August 19th, 1911, but I am of the opinion * * * that the result of the gagings are somewhat high."

In the following table the run-off results of Calaveras and Arroyo Valle, computed by the Spring Valley Water Company during the present spring, are set side by side with the respective seasonal gross run-off data recorded for the *entire Alameda Creek watershed* for the four consecutive seasons, 1904-05 to 1907-08 (inclusive).

Season—	Gross Seasonal Runoff from Entire Alameda Creek watershed. (M. G.)	Run-off computed for Calaveras (as furnished me in August, 1911). (M. G.) round figs.	Run-off computed for Arroyo Valle Reservoir site (computed in spring of 1912). (M. G.) round figs.
1904-05	20,254	16,540	4,200
1905-06	63,134	32,550	17,000
1906-07	102,917	54,500	31,700
1907-08	21,189	14,140	3,300
Totals	207,494	117,730	56,200
Average—			
Per annum	51,873	29,430	14,050
Per day	142	80	38.5

With, say, 10 per cent deducted from the above average Calaveras result of 80 million gallons per day (as suggested by me above), we shall have the following gross average results for this 4-year period for:

Entire Alameda System	Calaveras Reservoir	Arroyo Valle Reservoir
142 M. G. per day.	72 M. G. per day.	38.5 M. G. per day.

If we carry out the above 10 per cent. reduction from the average records at Calaveras for each individual year of this period, we would have the following yearly run-off results, which in my opinion represents approximately

***In January, 1912.

the average annual run-off at Calaveras for this period, in round figures:

Season—	Calaveras gaging records if modified as above. M. G.
1904-05	14,800
1905-06	29,300
1906-07	49,000
1907-08	12,700
Total	105,800
Or an annual average of	26,450
Or, in round figures, *per day*	72

This represents the probable *gross average daily run-off* from Calaveras during said period.

By placing the run-off figures for the Arroyo Valle region side by side with the Calaveras results so corrected we have the following comparative run-off table for this 4-year period from 1904-05 to 1907-08:

Season.	Calaveras gross run-off (in mil. gals.), round figures.	Arroyo Valle gross run-off (in mil. gals.), round figures.
1904-05	14,800	4,200
1905-06	29,300	17,000
1906-07	49,000	31,700
1907-08	12,700	3,300
Totals	105,800	56,200
Average per annum	26,450	14,050
Average per day	72 mil. gals.	38.5 mil. gals.

The gaging records taken at Calaveras Reservoir site for the *5-year* period from 1898-99 to 1902-03, inclusive, give the following results:

Season.	Run-off gaged at Calaveras Reservoir Site (in mil. gals.), round figures.
1898-99	13,200
1899-00	14,400
1900-01	17,800
1901-02	11,000
1902-03	15,000
Total	71,400
Or annual average for five seasons	14,280

This represents an average for these five successive low seasons of 39.12 M. G. D.

The gross run-off results for the *5-year* (1898-99 to 1902-03) and for the *4-year* period (1904-05 to 1907-08) enable us by interpolation and comparison with the gross Alameda System run-off record for 19 years, to conservatively approximate the probable run-off from Calaveras for the remaining 10 years, during which no run-off record was available.

The following table shows the gross run-off down the Niles Canyon, as recorded by the Spring Valley Water Company, as well as the run-off from Calaveras, for nine years out of the 19-year period. The run-off figures, interpolated by me, are shown in italics:

RAINFALL AND RUN-OFF RECORDS IN VARIOUS PORTIONS OF THE ALAMEDA CREEK DIVISION (FROM JULY 1ST TO JULY 1ST), WHICH RECORDS I HAVE USED IN CONNECTION WITH MY STUDIES ON THE HYDROGRAPHY OF THIS REGION.

SEASON.	Gross run-off from Alameda System, through Niles Canyon (in mil. gals), Nov. 1 to Nov. 1.	Gross run-off from Calaveras Watershed proper (interpolated results in italics), (in mil. gals.), in round figures.	Lick Observatory (inches).	RAINFALL — Calaveras Reservoir Site (inches).	Sunol Valley (inches).	Pleasanton (inches).	Livermore (inches).	Arroyo Valle Reservoir Site. (inches).
1889-90	156,149	*65,000*	45.16	45.54	.....	.....	28.66	.....
1890-91	35,125	*17,000*	24.05	20.23	.....	.....	14.16	.....
1891-92	19.051	*10,000*	27.49	25.24	.....	.....	14.25	.....
1892-93	102,676	*45,000*	37.93	39.20	.....	.....	26.29	.....
1893-94	55,155	*25,000*	35.84	30.81	.....	.....	17.16	.....
1894-95	81,827	*35,000*	36.61	38.63	.....	.....	24.37	.....
1895-96	37,232	*18,000*	29.76	25.82	.....	.....	16.35	.....
1896-97	63,472	*29,000*	32.22	31.20	.....	.....	17.28	.....
1897-98	3,775	*2,000*	17.66	13.37	.....	.....	9.11	.....
1898-99	24,849	13,200	25.73	20.98	20.41	14.77	9.27	.....
1899-00	18,158	14.400	29.31	25.84	22.27	‡22.52	12.72	.....
1900-01	32,102	17,800	31.64	30.66	25.57	‡31.68	19.72	.....
1901-02	19,717	11,000	27.62	23.27	19.46	‡21.85	16.80	.....
1902-03	23,500	15,000	30.29	24.95	19.02	‡22.28	14.25	.....
1903-04	36,154	*18,000*	33.78	27.49	22.16	‡26.92	13.33	.....
Seasons from July 1 to July 1.								
1904-05	20,254	*14,800	28.55	28.72	†23.29	†23.82	15.81	.....
1905-06	63,134	*29,300	28.43	24.62	†25.21	†29.16	19.32	†20.48
1906-07	102,917	*49,000	43.34	35.94	†29.78	†32.03	23.14	†26.84
1907-08	21,189	*12,700	23.92	15.95	†16.70	†15.88	9.93	.....

Total for 19 seasons	441,200	mil. gals.
Average per annum	23,200	mil. gals.
Average per day	63.5	mil. gals.
Or, in round figures	63	mil. gals. per day.

*Original gagings, with 10% off.
†Rainfall was not available for my former reports.
‡Rainfall was available for my former reports, but has since been slightly corrected.

The actual average daily gross run-off from the entire Alameda System during the above 19-year period was in all probability somewhere between 140 and 145 million gallons per day, instead of the 132 million gallons recorded by the Company. As the above Calaveras results of 63 million gallons were arrived at without reference to the recorded gagings at Niles and Sunol it appears fair and conservative to reduce them in the same proportion between the mean of 140 and 145 on the one hand, and 132 on the other. This would reduce the above average gross daily run-off of 63 million gallons from Calaveras proper to its proper relation to the average gross daily run-off of 132 million gallons, or 58 M. G. D., which figure represents very closely the average proportion that the Calaveras watershed of about 100 square miles contributes to the gross run-off of the entire Alameda watershed.

B—The Run-off From the Arroyo Valle Watershed of About 140 Square Miles Area is 30 M. G. D.

The Company has gaging records on the Arroyo Valle Division for four years out of the above 19-year period. Computations based on this 4-year record gives an average of 38.5 M. G. D. as above shown.

This gross run-off of 38.5 million gallons per day at Arroyo Valle bears a relation to the average daily gross run-off at Calaveras proper for the same 4-year period of 72 million gallons per day or

$$\frac{38.5}{72} = 53.4\%$$

It is probable that a similar relation is maintained between the two run-off results for the 19-year period, which (as shown in the above table gives to Calaveras an average gross run-off of 63 million gallons per day) would give to the Arroyo Valle a gross run-off of fully 33 million gallons per day.

Applying the same reasoning used in reducing the 63 million gallons Calaveras run-off to 58 M. G. D., the Arroyo Valle figure of 33 M. G. D. becomes 30.3 M. G. D., or in round figures 30 M. G. D.

By adding together the above two average gross run-off results of Calaveras (58 M. G. D.) and Arroyo Valle (30 M. G. D.), we have a total for these two regions combined of 88 million gallons per day. The difference between the total average for the entire Alameda System (132 M. G. D.) and the Calaveras and Arroyo Valle combined of 88 million gallons per day is 44 M. G. D., which represents the gross daily run-off product from the remainder of the Alameda Creek watershed, with an area of about 380 square miles.

On accompanying Map A the various subdivisions of the Alameda Creek division of the Company's system are shown by division lines and black letters from A to F.

C—Run-off from Regions.

B.—Alameda Creek.
D.—San Antonio.
E.—Laguna and Sunol combined.

The rounded-off areas of the separate subdivisions of the entire Alameda Creek watershed, as herein adopted, are as follows:

	Sq. miles.
A.—Calaveras direct watershed.........	100
B.—Alameda tributary watershed......	35
C.—Arroyo Valle watershed............	140
C-1.—Arroyo Valle watershed (between reservoir and tunnel 41)...........	5
D.—San Antonio watershed............	40
E.—Laguna-Sunol and lower Calaveras..	80
F.—Livermore Valley gravel beds and tributaries incl. Mocho (but excl. Arroyo Valle)	220
Total area in round figures...........	620

As heretofore shown, the mean daily gross product from the Calaveras and Arroyo Valle direct watersheds amount to 58 and 30 million gallons, respectively, or jointly to 88 million gallons per day. The remainder of the gross average daily run-off from the entire Alameda Creek watershed is 132 million gallons, which leaves 44 million gallons per day, contributed by the other subdivisions, of about the following respective areas:

B—Of	round	35	square	miles.
C-1—	"	5	"	"
D—	"	40	"	"
E—	"	80	"	"
F—	"	220	"	"
Total area,		380	"	"

While the above two subdivisions A and C, of a joint watershed area of 240 square miles, or 38.7 per cent. of the entire watershed area, produce a daily average of 88 million gallons or 66.66 per cent. of the entire mean gross water yield of 132 million gallons per day, the remaining 380 square miles (B-D-E-C 1-F) or *61.3 per cent* of the entire watershed produce only *44* million gallons per day, or 33.33 per cent.

of this mean total daily water yield of 132 million gallons per day. The cause for this difference is that where subdivision A and C contain the highest and steepest mountain ranges and are good water-shedders the heaviest rainfall of the entire Alameda Division occurs in their upper reaches. In the remaining subdivisions, and about in the sequence of the above lettering, the ranges decrease in height and steepness of slopes, while the topography generally becomes more flat and the degree of absorption greater. At the same time the average seasonal rainfall also decreases from south to north, particularly from southwest to northeast.

Although as hereinabove shown, the gross product of this total northerly and northeasterly division of an area of round 380 square miles, averages about 44 million gallons per day, still, on account of the absence of separate stream gagings, the exact proportions of the subdivision of these waters (which together amount to one-third of the average gross water-product of the entire Alameda System of 132 million gallons per day) is not definitely known and has therefore to be arrived at by interpolation.

From my long and successful experience during fully four decades in proportioning the total run-off from a given district, amongst its main subdivisions, where only the gross run-off and specific rainfall data are available, particularly if the inquiry relates to regions (as in the case of the Alameda watershed) with the topography and hydrography of which I have been familiar for many years, I have been enabled, by considering all known contributary and contingent conditions and circumstances, to very closely proportion the run-off results to the different subdivisions in question.

The average daily gross run-offs from Calaveras proper (A) and Arroyo Valle proper (C) having been determined to equal respectively *58* million gallons and *30* million gallons, or together *88* million gallons per day out of the total average for the entire Alameda System of *132* million gallons per day, the next step will be to determine the average gross daily run-off from the group of watersheds numbered B-D-E and of a total joint area of about 155 square miles.

The Run-off from the Alameda Creek Watershed, Subdivision B.

Taking into consideration the Company's available rainfall data and the geographical location of these subdivisions with reference to each other and to adjoining watersheds of the Alameda System, reference to map A leads to the conclusion that the average rainfall on B will be somewhere near the mean between that taken at the Arroyo Valle and Calaveras Reservoir sites.

For this comparison the Company has only two years of rain record for Arroyo Valle, those of 1905-06 and 1906-07.

Season.	Rainfall, Calaveras.	Rainfall, Arroyo Valle.
1905-06	24.62″	20.48″
1906-07	35.94″	26.84″

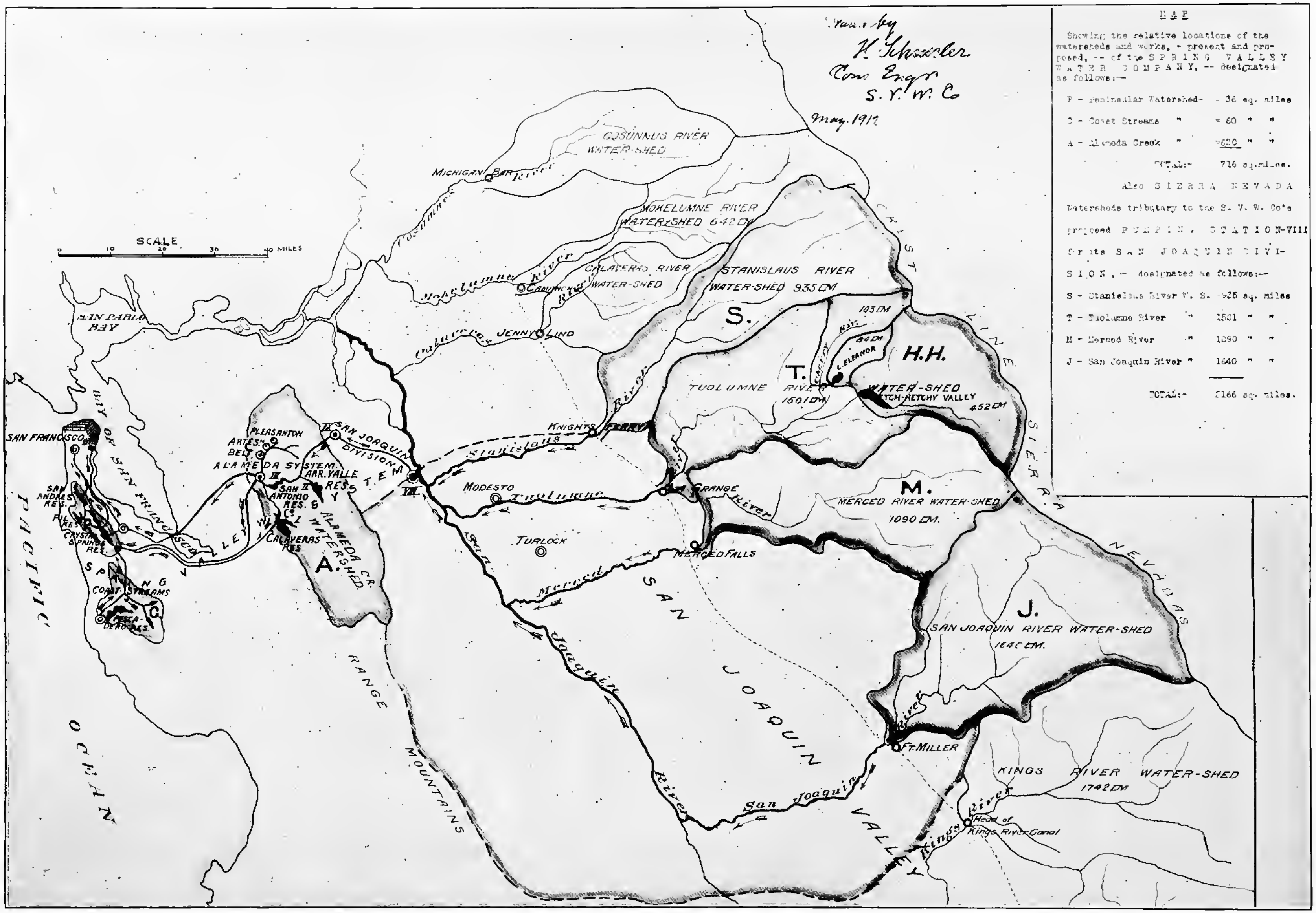
A comparison between these two sets of rain records shows that the average of the Arroyo Valle rainfall for these two seasons was 78 per cent of that of the Calaveras during this period.

The average rainfall taken during the above 19-year period at Calaveras Reservoir site being 27.80 inches we may assume that if the percentage relation, during the above two seasons, 1905-06 and 1906-07, between the Arroyo Valle and Calaveras rainfall of *78* per cent., continued approximately through the entire 19-year period, we would have an average annual rainfall in the Arroyo Valle watershed proper of between 21 and 22 inches per annum.

The average daily gross run-off from the Arroyo Valle watershed having been closely determined above to be about *30* million gallons per day, it appears that with an average seasonal rainfall of say 21 inches of rain on the 140 square miles, or round 3,900 million square feet of Arroyo Valle direct watershed, the average seasonal gross precipitation on the same would be round 6,800 million cubic feet, or 51,000 million gallons. The average run-off from the Arroyo Valle 140 square miles of watershed has been shown to be about 30 million gallons per day, or 10,950 million gallons per annum, indicating that on this watershed the percentage that the run-off bears to the gross precipitation would be about

$$\frac{10,950}{51,000} = 21.47\%.$$

The average annual rainfall on the *Alameda watershed* (B) of about 35 square miles will



RELATIVE LOCATIONS OF THE WATERSHEDS AND WORKS PRESENT AND PROPOSED OF THE SPRING VALLEY WATER COMPANY ARE HERE SHOWN AND COMPARED WITH THE WATERSHEDS AND HEAD WORKS OF SIERRA SYSTEMS. NOTE THE PROXIMITY OF THE SPRING VALLEY SYSTEM TO SAN FRANCISCO AND ITS ADAPTABILITY TO CONSERVE THE SPRING FRESHETS OF THE SAN JOAQUIN.

probably lie somewhere midway between that of *Calaveras* and *Arroyo Valle.* Where the Calaveras rainfall for the 19 seasons averaged about 27.8 inches, and that at Arroyo Valle (obtained as above by interpolation) about 21 inches, the average between these two rainfalls in round figures, about 24 inches, represents the average annual rainfall on the Alameda watershed. The topograhical as well as the geological features of the *Alameda watershed* (B) represent a medium between that of the *Arroyo Valle* shed (C) and the *Calaveras* (A). Located as it is, between C and A, its rainfall as well as its run-off will lie somewhere between those of C and A.

While the run-off percentage at Calaveras, from the average rainfall of 27.8 inches (during the 19 year period), owing to favorable conditions, shows an average percentage of 43.8%, the less favored *Arroyo Valle* region, with its rainfall of about 21 inches, shows a percentage of only about 21.5%. Where, as above stated, I place the average rainfall on B at about the mean between that of Calaveras and Arroyo Valle, I am convinced that the average run-off percentage on the *Alameda* (B) will be somewhat below that mean. While the run-off percentage of Calaveras is 43.8% and that of Arroyo Valle is about 21.5%, I am convinced that the run-off percentage on Alameda (lying between Arroyo Valle and Calaveras) is at least 20% greater than the average percentage of Arroyo Valle. This places the percentage of Alameda at about *25.8%*, which I shall round off to 25%.

The average precipitation on the 35 square miles of Alameda Creek, or round 975 million square feet of watershed, with an average rainfall of about 24 inches, amounts to a round 1,950 million cubic feet, or about 14,600 million gallons per annum. Of this gross annual precipitation, 25% equals an average run-off from Alameda Creek of 3,650 million gallons per annum, or 10 million gallons per day, which represents the probable average daily gross water produce of the *Alameda Subdivision* (B).

The Run-off from the San Antonio Watershed D, Lower Arroyo Valle C, and from the Sunol-Laguna Region E.

As heretofore stated, the first and third of the above three regions are intimately connected with each other both geographically as well as hydrographically. The third (C-1) will be connected with the San Antonio-Sunol-Laguna region by the construction of the proposed tunnel (41) from the Arroyo Valle to the San Antonio Reservoir. These three subdivisions have a gross watershed (in round figures) of about 125 square miles, of which D contains about 40, E 80, and C-1 5 square miles.

In order to arrive approximately at the average annual rainfall over this combined area of about 125 square miles, I shall take the mean of the rainfalls as recorded at Calaveras, Sunol, Pleasanton and Livermore and as recorded and interpolated for Arroyo Valle. This mean will be very close to the average rainfall on the entire 125 square miles during the ten seasons from 1898-99 to 1907-8 inclusive. The following list gives the average seasonal rainfall for these 10 years for the five stations, obtained as above shown:

	Inches.
Calaveras	25.84
Sunol	22.38
Pleasanton	24.09
Livermore	15.42
Arroyo Valle (as interpolated)	21.00
Total	108.73

$$\text{Average} = \frac{108.73}{5}$$

or 21.7 inches or (round figures) 21 inches.

This represents for the above ten-year period, the approximate mean rainfall over the three regions (San Antonio, Sunol-Laguna and Lower Arroyo Valle) of a gross watershed area of about 125 square miles.

While the rainfall conditions on these 125 square miles of watershed are fair, in that the average annual rainfall is fully 21 inches, or about equal to that on the Arroyo Valle proper, still owing to the preponderance of large flats and gently undulating hills covered with a more absorptive character of soil, my observations have convinced me that barely 60% of the run-off percentage of Arroyo Valle, or 50% of that of the Alameda region, can be counted upon, for this combined watershed.

Thus, where the former run-off percentage from about the same average annual rainfall (21″) is 21.5%, and that of the latter from a somewhat heavier rainfall (24″) is about 25% (sixty per cent of 21.5% is 12.90% and 50 per cent of 25% is 12.50%), it

is safe to say, that the average percentage of run-off on the entire 125 square miles, comprised within the watersheds of *San Antonio, Sunol-Laguna* and Lower *Arroyo Valle,* will probably not exceed 12.5 per cent of the average gross precipitation. The area of the 125 square miles of these combined watersheds, equals in round figures 3,485 million square feet. An average rainfall of 21 inches or 1.75 feet on this surface represents round 6,100 million cubic feet or 45,750 million gallons of gross precipitation on the watershed. Twelve and a half per cent run-off from this amount equals 5.720 million gallons per annum, or *15,660,000* gallons average daily run-off, from the San Antonio (D), the Sunol Laguna (E) and Lower Arroyo Valle (C-1) combined.

The run-off from that portion of the Livermore Valley Region—including Arroyo Mocho (but exclusive of Arroyo Valle proper, C, and of Lower Arroyo Valle C-1) —which is tributary to the Artesian belt on the Spring Valley Water Company's Pleasanton Properties.

This region (marked F on map) has an area of round 220 square miles, of which the average rainfall is not definitely known, but which, owing to the portions with light rainfall along its easterly margin, will probably not be much greater than the average rainfall at the town of Livermore, which lies practically in the geographical center of the region. The average rainfall at Livermore during the above period of 19 years, from 1889-90 to 1907-08 inclusive was 16.94 inches. Precipitation of 16.94 inches, or say 1.4 feet on the watershed of 220 square miles, or round 6,130 million square feet, represents a gross average precipitation of 8,582 million cubic feet, or 64,360 million gallons per annum. The average run-off percentage of this area I estimate to be but very little, if any, in excess of 10% of the gross precipitation, so that the run-off from the above 64,360 million gallons of average annual precipitation would not be much in excess of 6,436 million gallons per annum, or *17,600,000* gallons daily, most of which finds its way into the subterranean gravel deposits of Livermore Valley.

RECAPITULATION.

Showing the average daily gross surface run-off products from the above seven subdivisions of the Alameda System:

	Mil. gals. per day.
A.—Calaveras	58
B.—Alameda	10
C.—Arroyo Valle	30
C-1.—Lower Arroyo Valle; D.—San Antonio; E.—Sunol-Laguna	15.66
F.—Livermore Valley incl. Mocho; excl. of C. and C-1	17.6
Total average gross product from entire Alameda Watershed of an area of about 620 square miles	131.26

During September of this year, or fully four months after writing my report of May 1, 1912, I received from the main office of the Company the Alameda Creek run-off record for the four seasons from 1908-09 to 1911-12, thereby completing a 23-year period of run-off records from that system.

The average gross run-off from the Alameda System for the 23-year period becomes

134.8 million gallons per day,

which, after deducting unavoidable losses by waste and evaporation, brings the net surface water product of the Alameda System to round

120 million gallons per day.

If to this amount there is added the gain or saving to be effected by reducing or preventing the evaporation now going on from the sub-saturated soils of Livermore Valley (variously estimated at between 10 and 20 million gallons per day), the daily average net product of the entire fully developed Alameda Creek System would probably be somewhere between

130 and 140 million gallons per day.

C.—The San Joaquin Branch of the Combined System of the Spring Valley Water Company.

Between what has been written heretofore in this report and the data furnished on the accompaying map, and on the diagram relating to the flood records of the San Joaquin River, with its three main tributaries above the Company's proposed point of intake (VIII on map), very little remains to be said about this latter practically inexhaustible source of water supply. This source will be used only after the first heavy floods of each season have thoroughly cleansed and scoured each of the main water-bearing river channels. The above mentioned run-off chart speaks for itself. It indicates plainly, when, during each season, the proper

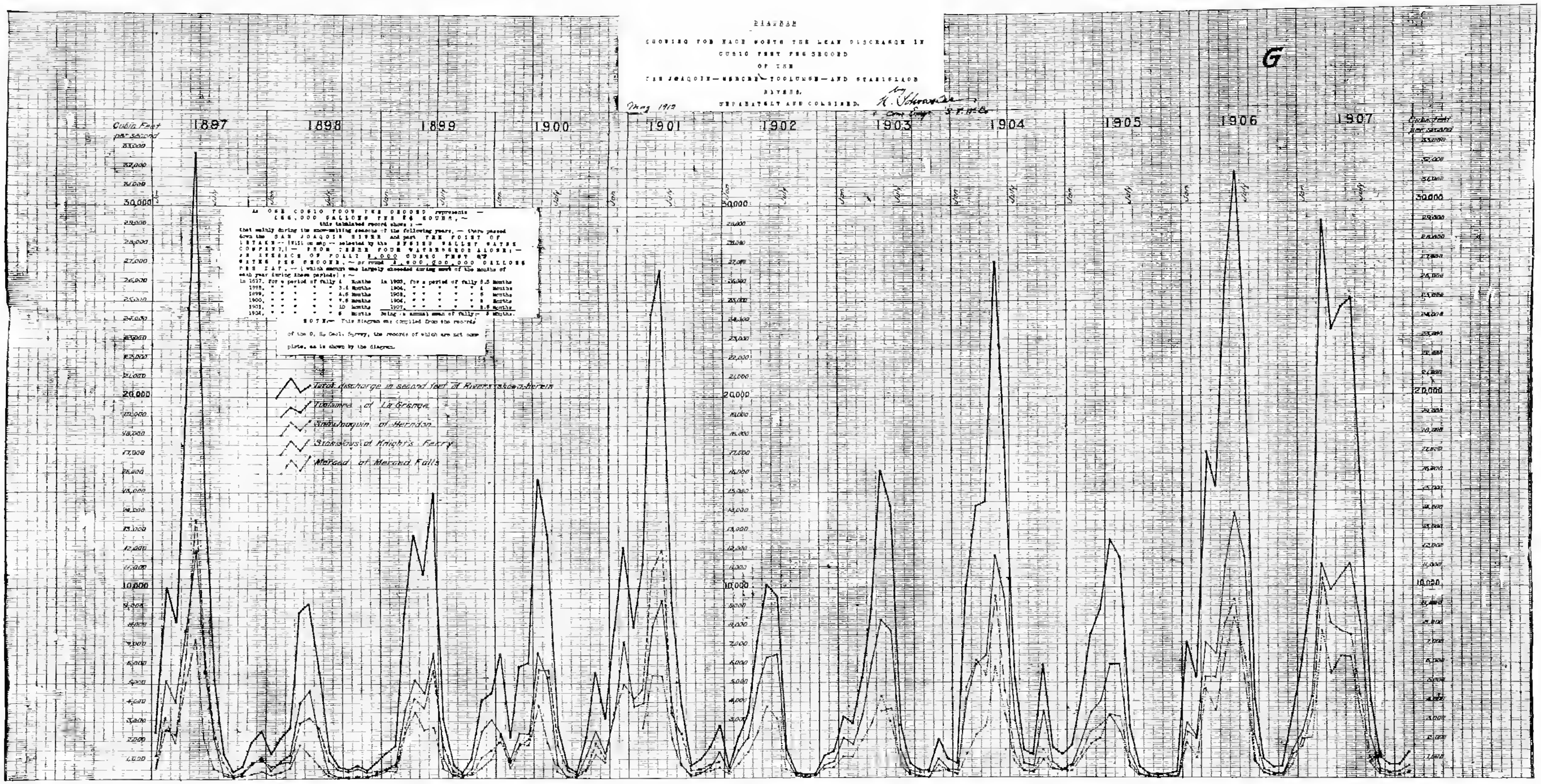


DIAGRAM SHOWING MONTHLY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE SAN JOAQUIN, MERCED, TUOLUMNE AND STANISLAUS RIVERS.

time has arrived to take water out of the river (which water during the snow-melting seasons is soft). It also shows, that the combination of the San Joaquin division with the Alameda and Peninsular divisions of the Company's system, will provide GREATER SAN FRANCISCO with an abundant supply of potable water of first-class quality for an indefinite future. The supply from the combined sources of the Company as proposed, can gradually and economically be increased to practically unlimited proportions, when required, so as to supply the region around San Francisco Bay, during the remainder of, and beyond the present century.

Another great advantage offered by the addition of the San Joaquin source to the Company's system, will be, that it enables it to fully utilize the heretofore described, practically unlimited, natural filtration system of the Alameda Creek Division. Thus, the introduction of the San Joaquin snow-water supply as an important and practically inexhaustible feeder to the combined system of the Company, will insure for the future an abundant supply of water of excellent quality for San Francisco and Oakland and their future suburban extensions, as it can be passed through the vast natural filterbeds of the Spring Valley Water Company in Livermore and Sunol Valleys.

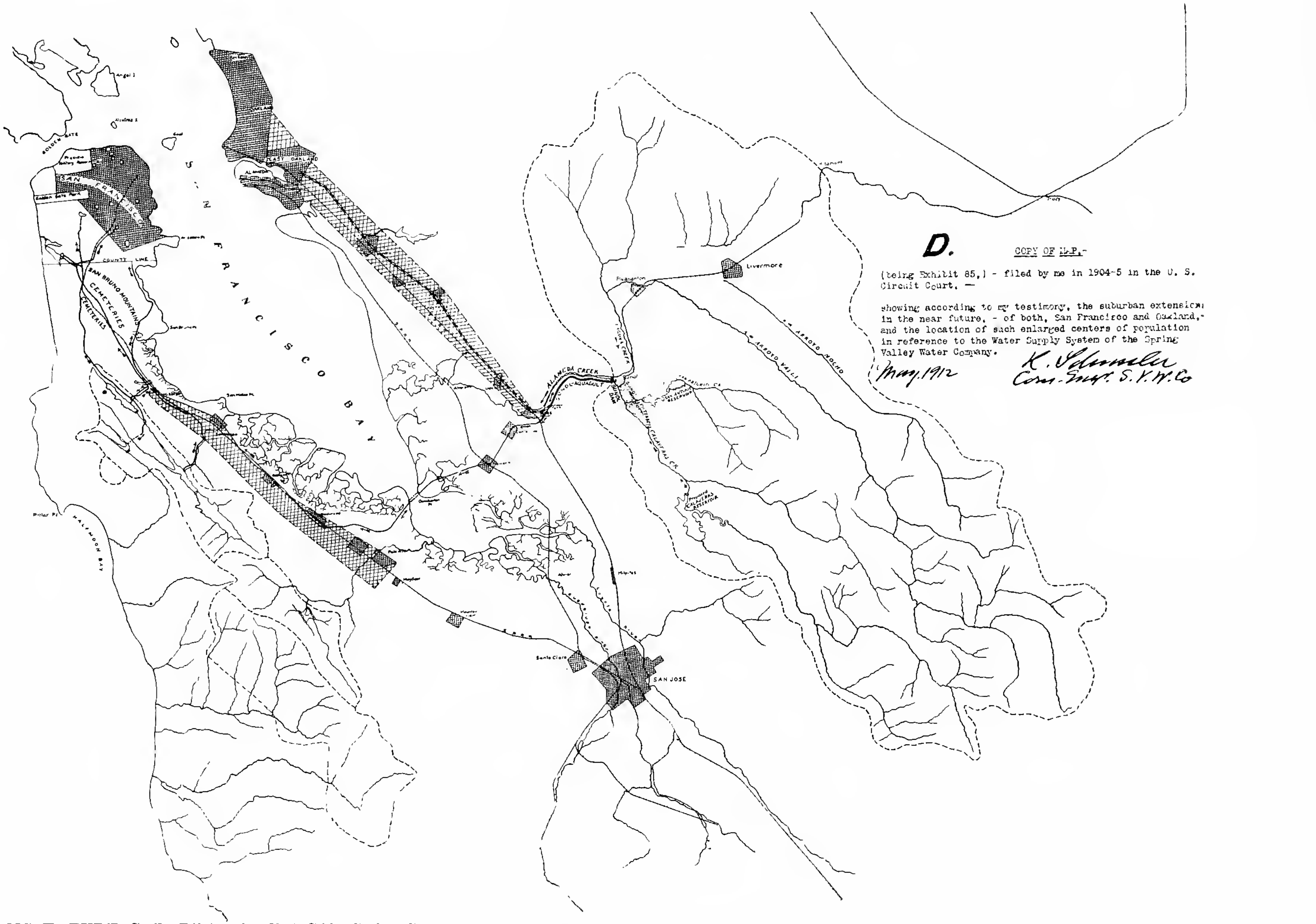
As hereinafter shown an additional supply of fully 50,000,000 gallons per day, can be developed on the Company's Coyote Creek properties and on its artesian properties south of San Francisco Bay and south of Gilroy. I have not taken them into consideration for the direct supply of San Francisco proper, as I am of the opinion that whenever it is desirable or has become necessary to develop these sources, their water yield, whole or in part, will then probably be required for the future southerly suburbs of Greater San Francisco located on both sides and south of the Bay.

The Niles Cone.

It has been variously argued that the residents on what is known as the "Niles Cone," which lies between Niles and the bay-marshes, might object to the final, full development of the Alameda Creek System, as in their opinion their subterranean water resources might be endangered thereby. The entire region underlying and adjacent to the southerly portion of San Francisco Bay is provided by nature with a large subterranean water supply, which is the result of water that has sunk into the porous gravel beds of the many streams traversing the extensive watershed surrounding the southerly half of the Bay. Alameda Creek is one of these feeders, but a comparatively small portion only of its run-off waters sink into the substrata underlying the so-called Niles Cone. By far the largest portion of the water, during the winter freshets rushes to, and is lost in the waters of the Bay.

Thus, the summer and fall supply from the Alameda Creek System (which has been and is being utilized by the Spring Valley Water Company) would constitute the main feeder for the subterranean supply during this period of the year, in addition to the comparatively small amount that seeps into the substrata of the cone or delta during the freshet season.

By a large expenditure of money the Spring Valley Water Company has acquired from each of the property owners along Alameda Creek from the Sunol Dam to tide-water the right to divert all of the flow of Alameda Creek. These grants provide that the Company has the right "to impound, appropriate and perpetually divert and take the water from said Alameda Creek and all of the tributaries and feeders thereof, for the uses and purposes of the Water Works of the Company." Owing to the rapid suburban growth on both sides of the Bay, which will largely increase in the future, it is only a question of a few decades at most, and long before the Alameda Creek Division of the Spring Valley Water Company's combined system is, or needs to be, fully developed, that practically the entire region now known as the Niles Cone, will have become too valuable to use for fruit-raising purposes as at present, but will have instead, been turned into suburban property with a large population, requiring a properly constituted water-supply system with distributing pipes in the streets, and reservoirs on the elevations. At that time, the residents of what may then be called "the Niles borough," will not only need, but will clamour for the filtered water from the Alameda Creek Division to be delivered to them through their local distributing pipe system under pressure.



SHOWING FUTURE SUBURBAN EXTENSIONS OF SAN FRANCISCO AND OAKLAND AND THEIR RELATION TO THE WATER SUPPLY SYSTEM OF THE SPRING VALLEY WATER COMPANY.

During the Spring Valley Water Company's suit in the U. S. Circuit Court, I furnished a map (Exhibit 85) relating to the subject of future water requirements in the suburban regions on both sides of San Francisco Bay. I shall here quote some extracts from my testimony given at that time of this subject:

(See page 1544 of Transcript of Testimony of H. Schussler, in 1904-5):

"I have prepared a map showing on both sides of the bay of San Francisco the present cities and towns in San Francisco, Alameda and San Mateo counties, also including Palo Alto, in Santa Clara County. These towns are shaded with small diagonal cross lines, while the regions in Alameda and San Francisco counties which are filling up rapidly with suburban population—which increase will be particularly noticeable during the balance of this decade and during the next one—are shaded with a coarser network of diagonal cross lines. Outside of San Francisco, Oakland, Alameda and Berkeley—particularly the two suburban regions that are shown on the map—will receive a large proportion of the increase of population in these two counties. I herewith present this map, which will be Complainant's Exhibit 85."

"This map is entitled 'Map showing present centers of population on both sides of the bay of San Francisco; and the probable future aggregation of population,—thus' (indicating); 'also showing approximate convenience and availability of the sources of water supply, present and future; scale, half inch to one mile."

(See page 1547 of Transcript of same Testimony of H. Schussler, in 1904-5.)

"The Sunol Valley filter beds, of an area of nearly 1,000 acres, are so located that the water product of the three proposed reservoirs, namely, the Calaveras, the San Antonio and the Arroyo Valle, can and will be thoroughly filtered through the same by gravitation, before being sent by way of the Sunol aqueduct down through the Alameda Creek canyon to and into the Niles screen house, which, as I stated before, is and will be the central distributing point of water, at an elevation of about 180 feet above tide, either for San Francisco's city and county, with or without its suburban regions of San Mateo county, or for both these counties combined with the principal cities and towns and suburban region rapidly growing up in Alameda County, which region is rapidly extending, in a southeasterly direction, toward the distributing point at Niles; the growth of both suburban districts on either side of the bay being fostered by rapid electric car service.

It is the close proximity of the magnificent Alameda Creek system, with its vast watershed, its fine storage reservoir sites and its unparallelled filter bed system, to these same centers of the rapidly growing population on the east side of the bay that lends a large additional value to the combination, in the Alameda Creek System, of the water rights, reservoir sites, watersheds and filter beds over and above its value if considered exclusively for the purpose of San Francisco, city and county."

The following gives a brief synopsis of the interconnection of the various subdivisions of the works hereinabove outlined, which when completed and in full operation, will take care of the water requirements of the population that may gather around the shores of San Francisco Bay in the distant future.

In this enumeration I have not followed the sequence with which the developments of the various subdivisions are likely to proceed, as that may depend partly or largely upon circumstances and advisability at the time.

GENERAL OUTLINE OF THE MAIN FEATURES OF THE WORKS OF THE COMBINED SYSTEM OF THE SPRING VALLEY WATER COMPANY AS HEREINBEFORE OUTLINED.

Note: Both Roman and Arabic numbers indicate the respective works, as shown on Map A and Profile E and as quoted in this report.

1.—Peninsular Division.

XI Crystal Springs Dam to be raised so as to give the reservoir a capacity of about 58,000 million gallons.

3a. Crystal Springs proposed Main Gravitation Aqueduct to San Francisco (large concrete-lined tunnel, under Bald Hill ridge. Capacity, 250 million gallons per day).

XVII. Crystal Springs Pumping Station, and

6. Conduit to San Andreas Reservoir both to be enlarged.

3. Crystal Springs Conduit, capacity to San Francisco to be enlarged.

1. San Andreas Conduit, capacity to San Francisco to be enlarged.

XVIII. Millbrae Pumping Station, capacity to be increased, and

13. New force-pipe and tunnel to San Andreas Reservoir.

XXIV. Central Pumping Station in San Francisco its capacity gradually and correspondingly increased, and

XXII. Industrial School large City Distributing Reservoir.

City Distributing System, correspondingly extended.

2.—Coast Stream Division.

48-47-46 45-44-43 Pescadero-San Gregorio combined main and storm-water aqueduct to Crystal Springs Reservoir.

XXVI. Pescadero Storage Reservoir.

XXVII. " Pumping Station.

50. " Force pipe and conduit to 45, and

49. San Gregorio feeder to Pescadero Reservoir.

3.—Alameda Creek Division.

I. Calaveras Reservoir of a proposed capacity of about 53,000 million gallons.

19. Outlet Tunnel for same, with

18. One or more iron pipe lines, across Santa Clara Valley, and

T 18. Tunnel into Crystal Springs Reservoir.

23. Northerly outlet tunnel from Calaveras Reservoir, and

23-a. Alameda Creek feeder to Calaveras Reservoir, and

26-29. Main Canal distributing Calaveras water over Sunol filter-beds 27.

II. Arroyo Valle Reservoir, of a capacity of 12,500 million gallons, and

40-41. Aqueduct and tunnel from Arroyo Valle to San Antonio Reservoir.

III. San Antonio Reservoir, of a capacity of 10,500 million gallons, and

42-29. Canal distributing San Antonio and other waters, over Sunol filterbeds.

32. Main Arroyo Valle filter-gallery.

32-a. Main Arroyo Mocho filter-gallery, both delivering by gravitation the water so obtained from the above two respective extensive gravel beds, through and along aqueduct.

31. To the Sunol Valley filter-beds, and to the

X. "Meeting of the waters" and main Sunol Valley Distributing and Pumping Station, combined.

NOTE: The function of the two extensive subterranean filter gallery systems in the Mocho and Arroyo Valle branches of the large Livermore Valley gravel sink is to draw the water (by a number of cross galleries each with many thousands of galvanized pipe inlets (like those now in successful operation in Sunol Valley) from underneath the respective broad and porous creek beds.

By constructing both these branches of proper dimensions and locating the main and branch galleries so that when required, especially during the rainy season in the direct watersheds, and during snow-melting season in the Sierras, they can be called upon to give a supply, eventually amounting to many hundreds of millions of gallons per day of filtered water.

The same rule holds good for the future extended subterranean filter gallery system in the Sunol Valley gravel beds, which will not only take care of the waters sent down from the Calaveras and San Antonio Reservoirs as well as the product of subdivision E, but also of such waters of the Arroyo Valle and San Joaquin, as may be sent via the San Antonio Reservoir, to the "meeting of the waters":—X, in Sunol Valley.

Thus by drawing large volumes of water through all these filter galleries during the seasons when the gravel channels, either naturally or by being supplemented from other sources, have a good supply of water running in them, a very much larger average daily supply can be obtained from them for each year.

IV-V-VI. Pumping Stations on the Company's artesian belt near Pleasanton, drawing their water supply by a system of suction pipes (similar to the system now in successful operation there) or by air-lifts, or by both methods combined, from several properly located groups of

30-30-30. Artesian wells, distributed over the above artesian belt. The water product of this well and pumping system will be discharged into and conveyed to the "meeting of the waters" (X) in the Sunol Valley, through the gravitation aqueduct—31-31-31.

VII. Laguna Creek Pumping Station, which, with a low lift, pumps such water as may pass down Laguna Creek, through branch Canal 28, into the distributing Canal 29 along the east side of the Sunol filter-beds, where it is joined by the waters coming from San Antonio (III) and Calaveras (I) reservoirs.

4.—San Joaquin Division.

VIII. Main intake low lift centrifugal pumping station, lifting water out of San

Joaquin River (see maps A, B and C) into the settling basins 34 (map A), from which after clarification it flows by gravitation along concrete lined canal to subsidiary settling basins 35, from which

IX. The *main San Joaquin Pumping Station* lifts the water through

37. Capacious wrought iron force pipe lines to and into

38. Tunnel under Livermore Pass, from which in turn it is discharged through and along

39. Concrete lined canal, which, while crossing the easterly portion of Livermore Valley, drops a portion of its waters (if required)

39-D. Into the gravel-sink of the Arroyo Mocho and

39-D-D. Into the gravel-sink of the Arroyo Valle, and discharging the balance of its water with or without an addition from Arroyo Valle Reservoir (II) through tunnel

41. Into the San Antonio reservoir. From there via Distributing Canal 29 and Sunol filter-galleries 27, into

X. "The meeting of the waters" in Sunol Valley.

25. Sunol Dam, carrying the filtered water from 27 across Alameda Creek, into and through

16. Sunol Aqueduct, consisting of concrete lined tunnels (and at present some flumes which latter will be replaced by concrete lined tunnels like the present ones), of a carrying capacity of about 66 million gallons per day, to

14. Present 36-inch Alameda pipe line with 4 submarine lines crossing navigable slough and San Francisco Bay at Dumbarton Point; thence continuing 36 inches in diameter to

XVI. Belmont Pumping Station, where the water is elevated and then flows in 36-inch pipe line

14. To Burlingame, where it joins

15. The new 54-inch Alameda pipe line. This in turn conveys the water to

XVIII. The Millbrae Pumping Station, which at present forces it into

L. The San Andreas pipe line, but which in the future, after

15. The 54-inch new Alameda pipe line has been extended from Sunol aqueduct 16, to

XVI. Enlarged Belmont Pumping Station and thence continued (15) to Burlingame, where it will connect with the new Alameda 54-inch pipe there.

17. Shows conduit, consisting of wrought iron pipe and concrete lined tunnel, through which the enlarged Belmont Pumping Station

XVI. Will discharge such waters coming via 25, 16, 14 and 15, as are not sent northwardly to XVIII, etc., into

XI. The Crystal Springs Reservoir. Just west of San Francisco Bay, by a series of connecting gates, a portion of the water coming through pipelines 18 or 20 from either Calaveras or Sunol, respectively, can be discharged into pipelines 14 or 15 or both, and can thus if desired be sent to

XVIII. Etc., via the Belmont Pumping Station XVI.

X. The main Sunol Pumping Station is erected, which lifts whatever quantity of water is required, through

22. Wrought iron force pipelines to and into

21. *"Upper Sunol Aqueduct"* (consisting of a succession of a number of short, concrete lined tunnels) to its junction with

20. Wrought iron pipelines, say sixty inches in diameter, of a daily carrying capacity of about 75,000,000 gallons each; these so-called "inverted syphon lines," while having the same levels at their inlets as well as outletss respectively, with line 18 (from Calaveras), parallels the latter, in its entire length until pipelines 18 and 20 after having passed for many miles over the Company's broad artesian belt south of S. F. Bay, discharge their waters jointly through

T-18. The Crystal Springs tunnel, into

XI. The Crystal Springs reservoir.

24. Near the easterly or inlet end of both sets of pipelines 18 and 20, is a set of connecting gates between these two lines, so that the water coming either via 21 or 19, can be discharged into Crystal Springs through either or both of these lines.

Power Plants.

For the purpose of operating the works, when partly or wholly completed as hereinabove outlined, it may be advisable to establish two Central Power Stations. The one, being located at (IX) on the San Joaquin Division (while the main pumping plant there is operated by first-class steam driven plunger pumps), an electric power plant at the same place, (where fuel is convenient by both water and rail), would develop the necessary power to operate.

The low lift pumping stations—VIII at the main intake on the San Joaquin, 1V-V-VI at Pleasanton artesian belt, and VII at Laguna Creek, and the high lift pumping station X in Sunol Valley, by which the filtered water is lifted into aqueduct 21 and flows from there via 20 and T-18 to and into the Crystal Springs Reservoir XI.

The *other Power Station* would probably best be located at XVI at Belmont, and (while the high lift pumping plant there would be steam driven, lifting the water via conduit 17 into Crystal Springs Reservoir) the electric power needed for the operation of Pumping Stations XVII, XVIII and XXVII (the latter at Pescadero) could be developed most conveniently at the centrally located Belmont Station XVI.

D.—Santa Clara Valley Division.

The Water Development on this division is intended for the future use of the region wherein these properties are located, namely: South, Southwest and Southeast and East of the Southerly portion of the Bay of San Francisco.

As in the near future a large suburban population is bound to accumulate here, either in boroughs of future "Greater San Francisco" or in other separate centers of population, these districts will require a general water-supply system under pressure.

The respective water properties of the Spring Valley Water Company located within and near these suburban regions are specially adapted for an effective and economical development of their water resources.

Coyote System Will Produce 20 M. G. D.

The Company's available rainfall and run-off data relating to the 110 square miles of watershed on the Coyote Creek are scant, so that I have had to approximate the probable average water yield by comparison with similarly situated properties of which the rainfall and run-off conditions are better known.

I have assumed that the average seasonal rainfall is somewhere between that of Gilroy (20.15 inches), and Arroyo Valle proper at about 21 inches, and furthermore that the run-off percentage conditions are similar to those of the less favorably located (from a geographical point of view) Arroyo Valle watershed. The Arroyo Valle with its 140 square miles of watershed averages about 21 inches of annual rainfall, with an average run-off of 30 million gallons per day; Gilroy, located about 6 miles southwesterly from the Coyote Reservoir site, has an average annual rainfall of a trifle over 20 inches. The Coyote watershed adjoins that of the Calaveras at its southeasterly end, where the rainfall is considerably in excess of 20 or 21 inches. It is safe to say that the average rainfall on the Coyote shed at least equals that of Gilroy of 20 inches, and that the daily run-off per square mile is about the same as that of the Arroyo Valle.*

The average daily run-off per square mile of Arroyo Valle watershed is about 215,000 gallons, Allowing for the slight difference in the assumed average rainfall on the Coyote of 20 inches, and the average rainfall of Arroyo Valle of 21 inches, I shall place the run-off of the former in round figures at 200,000 gallons per day per square mile of watershed. Thus the 110 square miles of Coyote watershed would produce not less than an average of about 22 million gallons per day, which I shall round off to 20 million gallons per day.

Artesian Region South of Gilroy Will Produce 14 M. G. D.

The artesian belt of the Company, located southeast of Gilroy, has a gross watershed lying to the northwest and west of the same, of about 170 square miles, about 140 square miles of which are tributary to the subterranean gravels and

*See "Arroyo Valle run-off."

artesian belt on the Company's properties there. The main creeks traversing this latter area are the Las Llagos Creek on the east and the Carnadero Creek on the west side of the valley. Both of these creeks being better run-off producers than the Arroyo Mocho and other tributaries to the Company's artesian belt in Livermore Valley, I am convinced, that where the watershed supplying the Livermore Valley gravel basin (exclusive of the Arroyo Valle watershed) yields only about 80,000 gallons per day per square mile, the watershed around Gilroy, of which about 140 square miles is tributary from the northwest to the Company's artesian belt, will send into the same and make available, a supply of not less than 100,000 gallons of subterranean water per day per square mile of watershed. This would represent an average supply to be obtained from this artesian region of about 14,000,000 million gallons per day.

Artesian Region Around Southerly Shore of Bay.

The artesian strata traversing the properties of the Company, which skirt the southerly and southwesterly portion of San Francisco Bay, receive their subterranean supply from the large watershed tributary to Santa Clara Valley. As near as can be ascertained, about 420 out of the round 600 square miles, of the total watershed tributary to the belt of marsh-land on the southerly margin of the Bay (neither of which figures include the 110 square miles of the Coyote) supply the above artesian region south and southwest of the Bay, through many subterranean channels. This artesian belt is directly connected with the beds of the many streams discharging into Santa Clara Valley through the large accumulations of porous gravel, which fill their beds after emanating from the foothills and which gravel-filled beds in turn connect subterraneously with the artesian strata south and southwest of and southeast of the bay. The conditions surrounding the water-supply to the above artesian belt, judging from my observations, are fully equal to those supplying the artesian belt southeast of Gilroy, which I estimated will furnish not less than an average of 100,000 gallons per day per square mile of watershed. Applying this rate (a very low estimate) to the artesian belt surrounding the south end of the Bay, and assuming that only one-half of this product passes through underneath the properties in question, we have an average daily water supply, that can be drawn from that region by a properly devised and distributed artesian well and pumping system, of not less than 21,000,000 gallons per day.

A recapitulation of the water products obtainable from the three above described sources for suburban supply purposes around and southeast of southerly end of Bay.

	Mil. gals. per day.
Coyote Reservoir and filter beds........	20
Artesian belt south of Gilroy............	14
Artesian belt south side of bay.........	21
Total	55
Which latter figure I shall round off to..	50

When it appears advisable to develop either partly or wholly, any one or more of the above three water resources, they no doubt will be used for domestic supply purposes, in the southerly portions of the proposed future *"Greater San Francisco,"* which will be located south of and on both sides of the southerly portion of San Francisco Bay.

Conclusions.

I shall here briefly recapitulate the results of my former estimates as well as those of my studies and conclusions, detailed in this present report, in order to see how my original figures on this subject (made during the nineties) compare with my present findings. I have shown that my first estimate of the water product of the combined Alameda System would equal about 200,000 gallons per day per square mile of watershed. With the area of this watershed as herein corrected, at round 620 square miles, this first estimate would represent in round figures about *124,000,000 gallons per day.*

In a subsequent estimate, made for the Board of Directors of the Company in the latter part of the nineties, I segregated the water yield into three subdivisions, as follows:

(1) Calaveras and Alameda watershed (herein placed at round 135 square miles) at an average yield of about 400,000 gallons per day per square miles of watershed, being, for 135 square miles, *54,000,000* gallons per day for Calaveras and Alameda combined.

(2) Laguna Creek, Sunol, San Antonio and Arroyo Valle combined, with a watershed as shown in this report as round 265 square miles, giving an average yield of about *200,000* gallons

per day per square mile, or *53,000,000* gallons per day.

(3) Watershed tributary to Pleasanton artesian belt (exclusive of Arroyo Valle) of round 220 square miles of watershed, supplying an average yield of about *100,000* gallons per day per square mile, or *22,000,000* gallons per day. By recapitulatiing these three results arrived at in the latter part of the nineties, we have—

	Gals. per day.
A.	54,000,000
B.	53,000,000
C.	22,000,000
Total	129,000,000

In my *"Review Report"* of January 22nd, 1912, after going carefully over my two last reports of August 19th, 1911, and of November 14th, 1911, on the subject of the water yield of the Alameda System, I segregated the system into two main subdivisions and estimated the relative net water yield of each, as follows: That of the southwesterly and westerly region, designated on map A herewith, by letters A-B-D-E, and comprising 100, 35, 40 and 80 square miles respectively, or 255 square miles collectively, and comprising the Calaveras, Alameda, San Antonio and Sunol-Laguna watersheds, at *74,000,000* gallons per day. That of the easterly and northeasterly region, consisting of the watersheds of Arroyo Valle C, of 140 square miles; the lower Arroyo Valle C-1, of 5 square miles; and the remaining region tributary to the artesian belt in Livermore Valley (including Arroyo Mocho), of round 220 square miles, making a total tributary watershed area of 365 square miles (comprised on map A under letters C, C-1 and F). I placed this region at an average net water yield, when fully developed, of *46,000,000* gallons per day. Thus the combined result of these latter two estimates was a total average net yield of *120,000,000* gallons per day.

During the last thorough investigation (as detailed in this report) made by me on this important subject (in which I made full allowance for possible waste of water during extra heavy winters, as well as an extra allowance for loss by evaporation), I took into consideration the conservative run-off as given by the Company's Niles and Sunol records, as well as other records of local run-off and rainfall. This resulted in the conclusion that the average net run-off from the entire Alameda Creek watershed was *120,000,000* gallons per day.

In the following table a brief recapitulation shows the future development proposed by the Spring Valley Water Company, whereby the increasing demands of San Francisco as well as of Greater San Francisco will be amply met for an indefinite future:

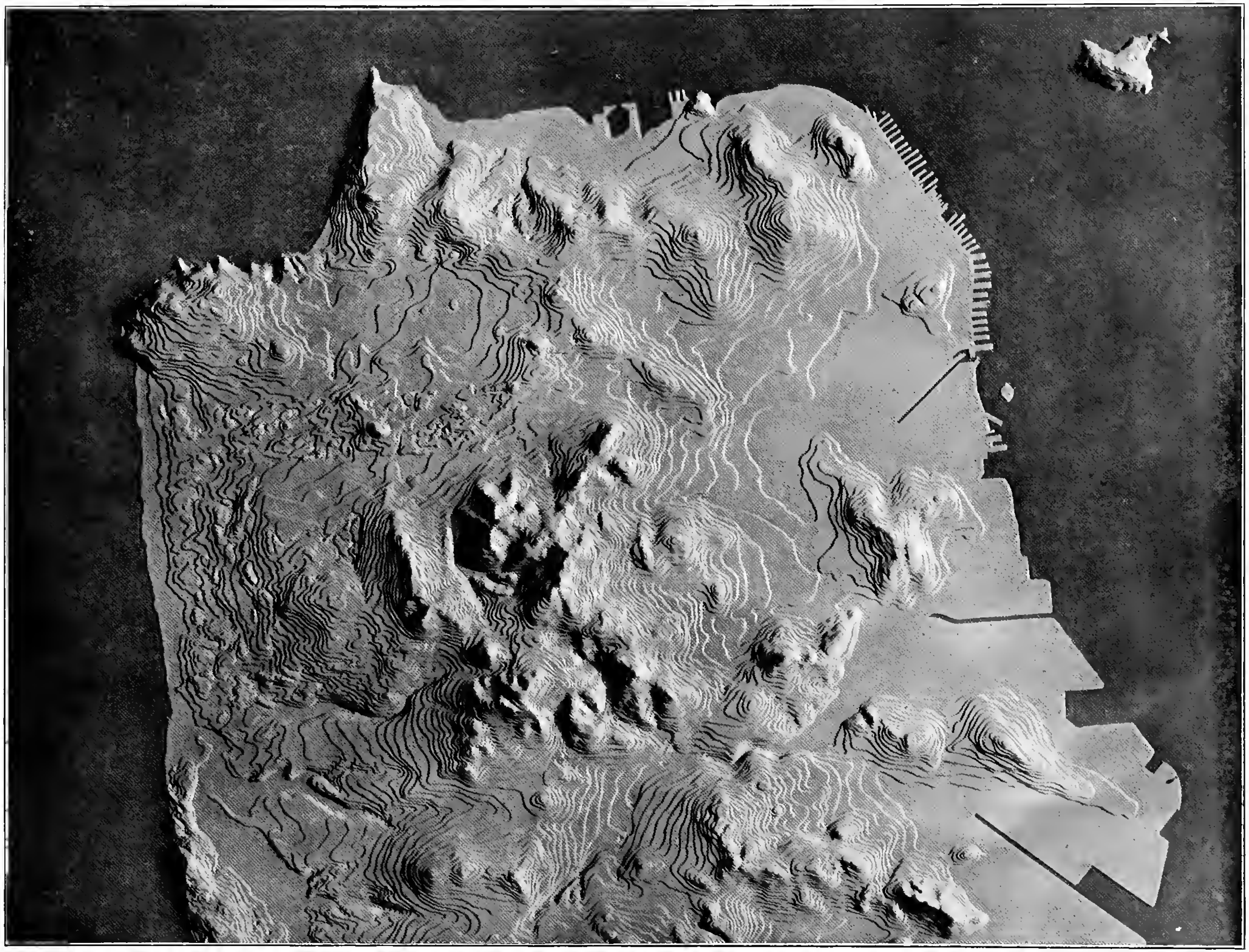
		Average net daily supply (in mil. gals.) round figures.
A. *Peninsular Division*		
Pilarcitos, San Andreas and Crystal Springs		19
Coast streams fully		50
B. *Alameda Creek Division*		
Calaveras	58	
Alameda	10	
Arroyo Valle	30	
Lower Arroyo Valle, San Antonio, Sunol-Laguna	15.66	
Livermore Valle, incl. Mocho, excl. Arroyo Valle	17.60	
Total gross	131.26	
Total net, 120.*		
C. *San Joaquin Division*		
With its practically unlimited supply as hereinabove shown.		
D. *Santa Clara Valley Division* (For suburban purposes only)		
Coyote River project	20	
South of S. F. Bay Artesian	21	
South of Gilroy Artesian	14	
Total	55	
Rounded off to		50

The System is a Unit.

All through this report I have emphasized the unit idea in constructing as well as in operating the Company's unequaled system. Under our variable climatic conditions, as illustrated herein, large storage reservoirs are absolutely necessary.

But this alone is not sufficient; they must also be interlaced and interconnected with each other so thoroughly that any part of the combined system can quickly and reliably be assisted by the other portions that have resources to spare. (See map A and diagram E.) If such assistance can be given by gravitation, well and good; if not, pumping will be resorted to. For this purpose, as well as in order to make some of the lower but very prolific reservoirs of our combined system quickly and economically available, our Company's plan of development includes several high duty pumping stations, located at strategic points from where water can be sent to the point where it is required, for a comparatively

*On page 118 of this report is shown under what conditions the above net water product of the Alameda System may be increased from 120 million gallons per day to between 130 and 140 million gallons per day.



CITY OF SAN FRANCISCO.
Note the Uneven Topography, Showing the Difficulties Which Must 'e Overcome in Supplying Water. Elevations Run from Sea Level to 900 Feet, and Lie Irregularly.

small capital expenditure as well as under a low operating cost.

Owing to the very uneven topography of San Francisco, the use of pumping plants, for the purpose of distributing water to the inhabitants living on the slopes and summits of the many more or less isolated hills and ridges within the City, has been resorted to in the past, and will have to be resorted to in the future.

With the exception of water supplied by way of the Spring Valley Water Company's San Andreas Reservoir (which will deliver water by gravity to the proposed "Industrial School Reservoir" at an elevation of 310 feet above tide) all other water supplies arriving in this City by way of the Crystal Springs reservoir and its future large gravitation tunnel-aqueduct (3-a on map A), whether coming from any of the subdivisions of the Spring Valley Water Company's System or from Sierra Nevada, by gravitation or otherwise, will probably not reach San Francisco at an elevation higher than about 190 feet above tide.

With the above exception, therefore, all of the future supplies which will be required above the level commanded by the main distributing reservoirs at an elevation of about 190 feet above tide, will have to be lifted by proper pumping-stations, located within the City at such points where the supply can be conveniently delivered from the outside works, and in the reasonably near neighborhood of which the respective higher elevations or summits, to which the water is to be delivered are conveniently located.

Water arriving in the lower main distributing reservoirs in San Francisco will supply that portion of San Francisco located between the shores of the bay and ocean on the one hand, and about the 100-foot contour on the other.

The percentage of respective areas covered by the regions located between the contour lines:

Below the 100-feet contour	40%
Between 100 feet and 200 feet	24%
" 200 " " 300 "	20%
" 300 " " 400 "	8%
" 400 " " 500 "	5%
" 500 " " 600 "	1%
Above 600 feet	.2%
Total	100%

This table shows that practically 60 per cent of the surface area of San Francisco will have to be supplied by the use of pumping plants.

The Spring Valley Water Company has found that the compactness of its system, which combines great versatility and a high degree of interchangeability with short safe lines of intercommunication between the various main subdivisions, as well as between them and the City, presents a strong array of factors of safety as well as factors that make for economy of construction and of operation. Our Company has had a vast amount of experience not only in the construction of proper works for water supply purposes, but also regarding the actual cost of works of this character under the prevailing conditions of labor and materials, and has thoroughly studied the plan of construction as well as the probable cost (even under the best management obtainable) of the various plans proposed to it for bringing by gravitation its future additional water supply from one of the Sierra Nevada sources. In these estimates it was contemplated to cross the San Joaquin Valley by means of so-called inverted syphon pipelines, discharging the water by gravitation through a tunnel under Livermore Pass at practically the same elevation as outlined in this report for its San Joaquin Division.

Subsequently, the investigations were concentrated upon the three distinct Sierra watersheds lying directly opposite to our proposed Livermore Pass tunnel (30 on map A), being that of the Mokelumne River of about 500 square miles, that of the Stanislaus of about 640 square miles, and that the Tuolumne of about 700 square miles of watershed area, respectively. Outside of the necessary head works for each of these three specific cases (the aqueducts terminating in the foothills of each respective canyon, at an elevation of 1,000 feet more or less above tide), one or more so-called inverted syphon pipes were to be constructed, reaching from the westerly termini of the respective aqueducts, across the San Joaquin Valley to the easterly or inlet end of the Livermore Pass tunnel. The total fall of these pipelines crossing the San Joaquin Valley (about 400 feet), between the easterly and westerly termini of the respective "inverted syphon pipelines," gave a fall or grade of about 6 feet per mile of pipe. This fall, for the contemplated pipelines of 62 inches diameter, corresponds to a discharge capacity for each line of about 60 million gallons per day.

My cost estimates for these pipelines were

based upon a quality of American laminated iron equal in every respect to that employed by the Spring Valley Water Company in the construction of its 44-inch Crystal Springs pipeline as well as of its 36-inch Alameda pipeline. Both of these lines, through their long period of successful service, have proven the true economy of proper proportions, high-grade materials and workmanship combined.

The actual cost of construction of gravitation works from the most favorably located one of the above three Sierra Nevada sources, per million gallons per day delivered by gravitation at the easterly or inlet end of our proposed Livermore Pass tunnel, was found to be more than three times the cost of works delivering the same amount of water by pumping from the San Joaquin River during the snow-melting seasons, as proposed by our Company and as outlined in this report.

The annual cost of operating the latter system, including all cost such as fuel, wages, interest, depreciation, etc., was found to be between one-half and two-thirds of the annual cost of the Sierra Nevada gravitation plan, including interest, depreciation, labor, etc.

Besides, the adoption of the Company's plan of taking the water out of the San Joaquin during the snow-melting period, not only connected our works with a source near home, of vastly greater furnishing capacity, but also, while saving a vast sum in the initial capital expenditure, it entirely avoided costly and tedious future litigation as to water rights, and, as above stated, the cost per million gallons delivered at the Livermore Pass tunnel inlet was between one-half and two-thirds only of the cost delivered by gravitation from the Sierra sources.

Thus it was evident that the plan adopted by the Spring Valley Water Company of connecting the San Joaquin River directly with the Alameda Creek Division of its works was by far the most practical, economical and rapid solution for its future extension, particularly, too, as thereby its resources became practically unlimited, and all ideas, therefore, of eventually adding a Sierra Nevada source to its system by gravitation were abandoned in favor of the plan herein outlined.

Where kind Providence has placed close to the eastern boundary line of the Alameda system in the San Joaquin River the marvelous run-off result from the snow-clad Sierras we are highly gratified at having selected this much more economical, as well as more safe and reliable source of future additional supply.

In short, the works of the Spring Valley Water Company (as outlined in this report) can furnish an abundant supply of water of first class quality, to the regions surrounding San Francisco Bay during the remainder of, and beyond, the present century.

> "The properties and works of the S. V. W. Co. occupy such a unique position that they will always constitute the nucleus as well as the only safe basis for all future water supply projects for San Francisco and the cities on both sides of the Bay."

Respectfully yours,

HERMANN SCHUSSLER,
Consulting Engineer of the Spring Valley Valley Water Company.

AVERAGE DAILY GROSS RUN-OFF FROM THE ALAMEDA SYSTEM AS RECORDED BY THE SPRING VALLEY WATER COMPANY, COMPARED WITH THE COMPUTED RUN-OFF, FURNISHED TO MR. FREEMAN BY MR. C. WILLIAMS, JR., IN THE LATTER'S REPORT ON THE WATER-YIELD OF THE ALAMEDA SYSTEM.

COMPILED BY HERMANN SCHUSSLER, CONSULTING ENGINEER, S. V. W. CO.
OCTOBER, 8TH, 1912.

1. Season.	2. Annual Run-off Record of the Spring Valley Water Company for Niles and Sunol Dams. Gross Run-off per Season in Million Gallons.	3. Average Daily Run-off in Milions of Gallons.	4. Run-off as Calculated by Mr. Williams from his Estimated Rain-Tables and Run-off Curves in Millions of Gallons per Day.†	5. Mr. Williams' Estimated List (Col. 4) With Average Daily Run-off‡ of 420.9 M. G. Inserted for Season of 1889-90.	6. Mr. Williams' Estimated List (Col. 4) With His Estimates of 168.1 for 1908-09 and 74.9 for 1889-90 Omitted, but With S. V. W. Co.'s Record of 420.9 for 1889-90 (Nov. 1 to July 1) Inserted.§
1889-90	156,148	427.9	.....†	420.9	420.9
1890-91	35,125	96.2	57.9	57.9	57.9
1891-92	19,051	52.1	89.3	89.3	89.3
1892-93	102,676	281.3	247.8	247.8	247.8
1893-94	55,155	151.1	102.5	102.5	102.5
1894-95	81,827	224.1	238.4	238.4	238.4
1895-96	37,232	102.0	104.8	104.8	104.8
1896-97	63,472	175.8	139.6	139.6	139.6
1897-98	3,775	10.3	17.7	17.7	17.7
1898-99	24,849	68.0	56.8	56.8	56.8
1899-00	18,158	49.7	79.7	79.7	79.7
1900-01	32,102	87.9	152.1	152.1	152.1
1901-02	19,717	54.0	80.9	80.9	80.9
1902-03	23,500	64.3	88.6	88.6	88.6
1903-04	36,154	99.0	85.9	85.9	85.9
1904-05	20,254	55.4	118.9	118.9	118.9
1905-06	63,134	172.9	163.5	163.5	163.5
1906-07	102,917	281.9	240.7	240.7	240.7
1907-08	21,189	58.0	43.9	43.9	43.9
1908-09*	.....	.....	168.1	168.1	.....
1909-10*	.....	.....	74.9	74.9	.....
	Average S. V. W. Co.'s record for 19 seasons..........	132.1	117.6	132.4	133.1
			Daily Average for 20 Seasons. Exclusive of 1889-90.	Daily Average for 21 Seasons. Inclusive of 1889-90.	Daily Average for 19 Seasons. (Inclusive of 1889-90, but exclusive of 1908-09 & 1909-10.)

*Seasons from Nov. 1 to Nov. 1.

†Seasons from July 1 to July 1.

‡For season from July 1 to July 1, so as to correspond with Mr. Williams' seasons (except 1889-90, which is from Nov. 1 to July 1).

§S. V. W. Co. has no record prior to Nov. 1, 1889.

†Although aware of the large run-off *recorded* during the season 1889-90, Mr. Williams omits the same, while he *retains* the very small run-off of the season 1897-98, thereby not obtaining a fair average for the 21 years from 1889-90 to 1909-10, of 132 million gallons per day, as shown in Column 5 of this table; but instead, thereby *lowering* the average by such omission to 117.6 million gallons per day as shown in Column 4.

By using Mr. Williams' *computed* figures for the 20 seasons from 1890-91 to 1909-10, and by adding thereto the run-off of 1889-90, the result for *these 21 consecutive years,* as shown in Column 5, is identical with my result, given in my previous reports, of 132 million gallons per day, while (as shown in Column 6), by taking *his computed* results for the 18 years from 1890-91 to 1907-08 (both inclusive) and for proper comparison adding thereto the run-off for 1889-90 recorded by the Spring Valley Water Company, thus encompassing *the same 19-year period,* as shown in Columns 2 and 3 (and upon which 19-year period, *my run-off result* of 132 million gallons, given in my previous reports is based), the *average daily run-off* for this period becomes fully *133 million gallons.*

Note:—The figures shown in Column 4 of this table were taken from a report on "the Water Supply of the Alameda Creek Watershed," made by Mr. C. Williams, Jr., to Mr. P. V. Long, City Attorney, which latter report I did not see until about five months after my present report of May 1st, 1912, was written.

By attaching Columns 4, 5 and 6 to the S. V. W. Co.'s run-off table (with Columns 1, 2, 3), we obtain the above comparative results.

REPORT ON THE POSSIBLE YIELD FROM THE ALAMEDA, THE PENINSULA AND THE LAKE MERCED SYSTEMS OF THE SPRING VALLEY WATER COMPANY

BY

George G. Anderson, C. E.,
Consulting Engineer.

San Francisco, Cal., September 12, 1912.

S. P. Eastman, Esq., Vice-President and Manager S. V. W. Co., San Francisco.

Dear Sir:

The following report embodies my conclusions regarding the possible water yield from Alameda System, Peninsula System and Lake Merced System of the Spring Valley Water Company.

General.

These conclusions have been derived after inspection in the field of the territory concerned, and after exhaustive, detail study of all data available and previous investigations of record.

The natural flow set forth for each of the systems in past years represents without doubt actual conditions within close limits.

The regulated flow or yield of the system presented, shows the supply of water that I estimate could have been delivered during the past years, with the structures and works mentioned, and under operating methods and right of control of water indicated.

I have not investigated titles or evidence of ownership to riparian and other water rights, but have accepted the Company's statement of right to the flow.

I am of the opinion that the data collected in my investigations is reliable, and that the estimates and deductions based thereon are sound and conservative, and that under normal and proper conditions, these conclusions will be substantiated.

Procedure of Investigations.

In the form of appendices to the following report is indicated the various records and documents from which the information, on which my conclusions are based, has been derived.

This underlying data has been checked and scrutinized with great care. All original field notes available have been inspected, and the summarized amounts shown in tabulations included in this report, have all been re-calculated and checked.

Field notes and daily journals have been accepted as correctly stating observations. In cases of doubt comparative and confirmative information has been searched for, carefully compared and the most conservative conclusion adopted. (The data referred to appears herein as Appendix H and Appendix I.)

Present Resources Capable of Large Future Extensions.

The Spring Valley Water Company's present water supply to San Francisco is drawn from the following three principal systems: Alameda, Peninsula and Lake Merced Systems.

The Alameda System draws water from the flow of Alameda Creek drainage area above the Company's diversion dam at Sunol. The surface run-off is regulated by pumping at Pleasanton Pumps from the deep and porous gravel basin in the Pleasanton-Livermore Valley, into which sinks surface flow from the streams.

It is proposed to largely increase the present

supply from this system by construction of reservoirs and additional pumping plants.

From Sunol the water is carried by aqueduct and pipe line down Niles Canyon, across the Bay of San Francisco at Dumbarton and up the Peninsula to Millbrae, where it ordinarily joins the Crystal Springs flow and can be diverted to join to San Andreas-Pilarcitos flow. On the way from Sunol to Millbrae the pumping plant at Belmont maintains the velocity of flow.

Distance from City Hall to Sunol Dam, 47 miles.

The Peninsula System, containing three storage reservoirs—Crystal Springs, San Andreas and Pilarcitos—is located on the San Francisco Peninsula, south of the City. The reservoirs are fed by surface run-off, and the water is carried by pipe lines and aqueducts to the City.

Ordinarily the system is at present operated in two units. Crystal Springs Reservoir feeds by gravity flow into University Mound Distributing Reservoir. San Andreas-Pilarcitos Reservoirs feed by gravity into some of the higher City Distributing Reservoirs. These two units are interconnected at Millbrae Pumps, where water from Crystal Springs supply can be pumped into San Andreas-Pilarcitos line if required; thus providing a valuable feature of interchangeability for the full utilization of the flow to the reservoirs.

Increase in the capacity of the reservoirs is possible.

Distance from City Hall to Crystal Springs outlet, 20 miles.

Distance from City Hall to San Andreas outlet, 14 miles.

Lake Merced is located in the southwest part of San Francisco, largely within city limits. The regulation reservoir is the lake itself, fed by springs and surface run-off. The location of the lake is near sea-level and the water is pumped directly from the lake into the distributing reservoirs.

Distance from City Hall to Lake Merced, 6 miles.

Water from any of the above systems can be led to all the distributing reservoirs, giving great flexibility to the control and safety of supply.

ALAMEDA SYSTEM.

Total Flow of Alameda Creek and Tributaries Above Sunol Dam.

Water appearing as stream flow within the Alameda Creek drainage area, flowing from the various tributary areas to join the main stream above Sunol Dam, departs from the drainage area partly as flow passing Sunol Dam and partly as evaporation from the water while in transit.

The flow at Sunol generally constitutes the larger quantity, but in years of light rainfall, when the run-off at Sunol is greatly decreased, the proportion of water lost by evaporation becomes considerable.

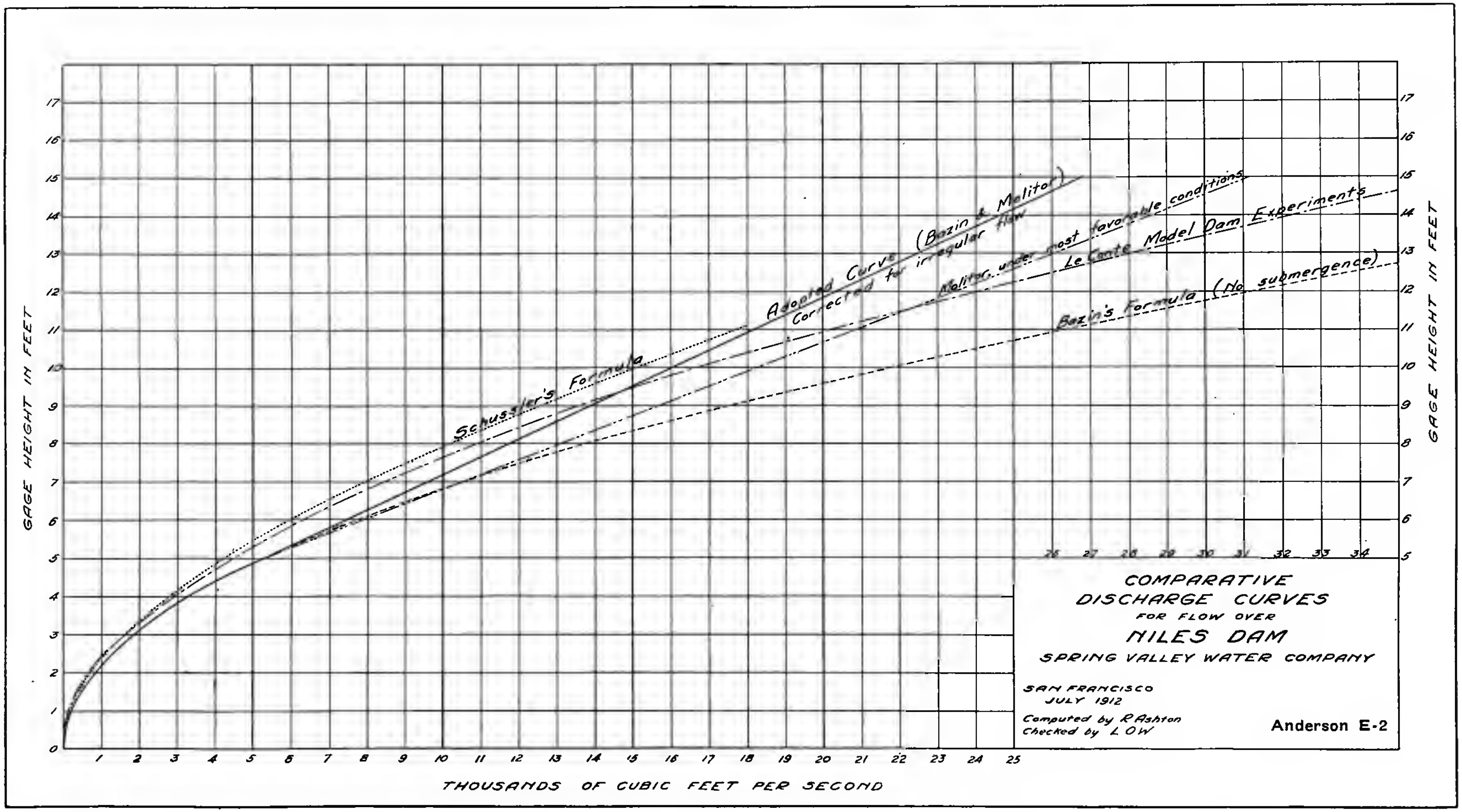
The principal evaporation loss occurs when the waters from the easterly tributaries pass with retarded flow the extensive gravel basin and lagoon lands in Livermore-Pleasanton Valley on their way to the outlet of the drainage area at Sunol.

At Sunol Dam the waters of Alameda Creek are divided into two parts. A portion is diverted by the Spring Valley Water Company and carried away by the Sunol Aqueduct; the remainder is discharged into the Niles Canyon, passing first Sunol Dam and later over Niles Dam.

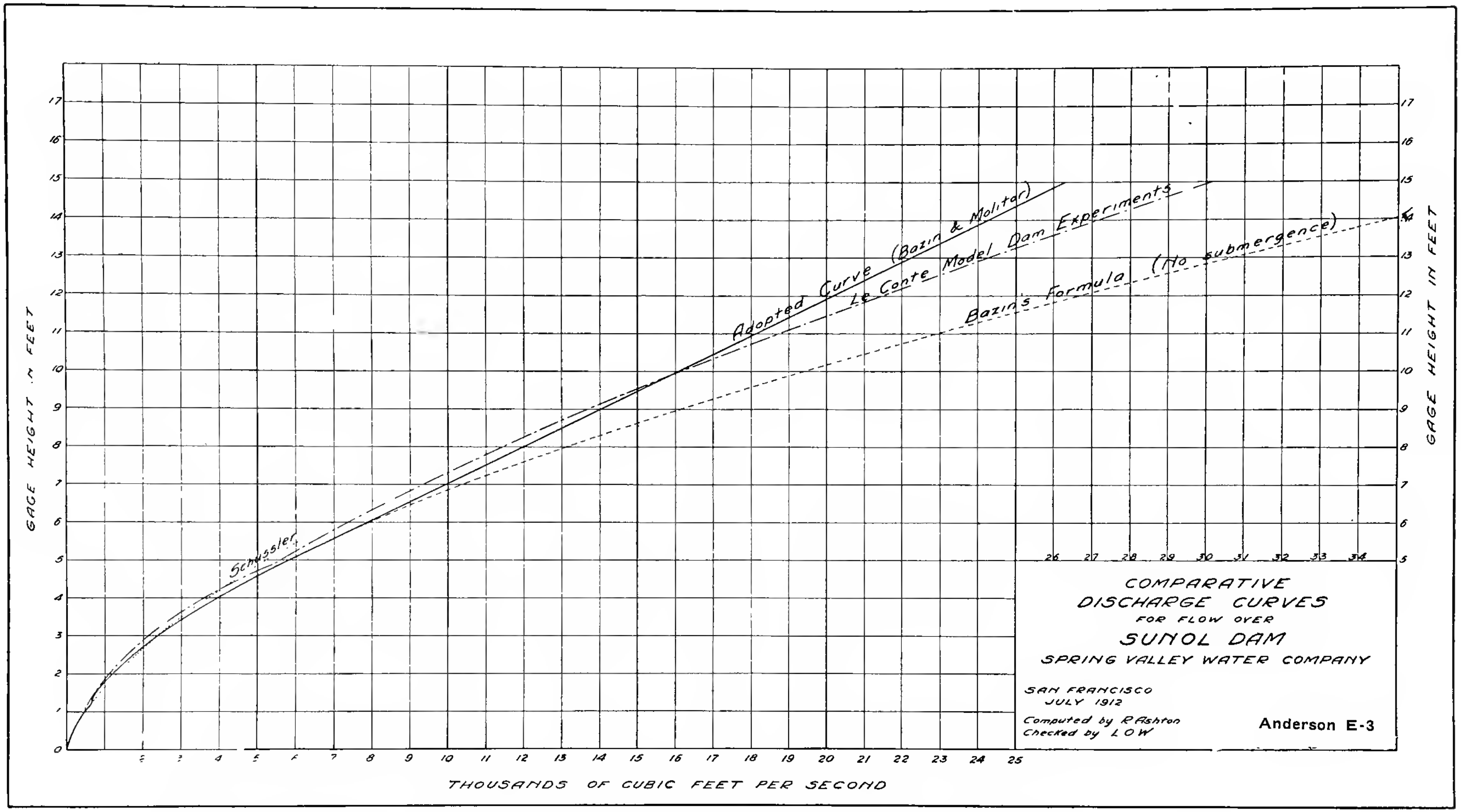
The water diverted at Sunol has, since 1906, been measured by weirs at Brightside. The main portion of the diverted flow is also shown by the records of pumpage at Belmont. The pump records commence in 1888.

The records of the pumping at Belmont have been checked and recomputed, and the records of measurements at Brightside weir have also been carefully checked. They are shown in tabulation.

To determine the amount of diverted flow, the records of the pumping at Belmont have been accepted in preference to the Brightside results. The two agree closely, considering the use of water between Brightside and Belmont, but there are some breaks in the Brightside records, and, altogether, the Belmont records are considered the more reliable and cover a longer period.



SHOWING VERY CONSERVATIVE COMPUTATIONS OF FLOW OF ALAMEDA CREEK HERETOFORE USED BY MR. HERMANN SCHUSSLER.



SHOWING CONSERVATIVE CURVE HERETOFORE USED BY MR. HERMANN SCHUSSLER IN COMPUTING FLOW OF ALAMEDA CREEK.

Records of Overflow Measurements at Niles and Sunol Dams Form the Basis for a Correct Statement of Stream Discharge.

The records of gage heights at the dams have been minutely examined and great care has been exercised in the notation of the respective widths of the dam, to which these heights apply from time to time.

These gage heights have, apparently, been accurately kept, and if due cognizance is taken of their relation to the lines of the structures, especially of the Niles Dam, they are satisfactory as a basis from which to build up a substantially correct statement of the stream discharge.

As is common in such observations, and was more common some years ago than it is now, the measurements of flow over the Niles Dam were made 24 hours apart, and only a few intermediate gagings were made at flood stages during the period of 12 years of observation at this dam. More frequent records during such floods would have given a more accurate presentation of the total discharge.

At the Sunol Dam, much more frequent observations were made. The result is a profile of gage heights more closely following the fluctuations of the stream.

Increase in Flow Over the Niles and Sunol Dams, Due to "Velocity of Approach," Entirely Neglected in Computations Heretofore Used by Spring Valley Water Company.

The tables of stream discharge over the dams heretofore used by and in the files of Spring Valley Water Company were calculated from the gagings by means of a weir formula, that may not apply with sufficient accuracy, alike in regard to the form of the dams, the feature of submergence, and, most vitally important of all, the neglect of all consideration of the effect of "velocity of approach", which on both structures is quite marked.

The discharge has therefore been recalculated, using the most recent and generally adopted methods and experiments, in order to arrive at rating curves that would correctly and conservatively indicate the discharge at the various stages.

The curves established by Prof. Le Conte, as a result of his recent experiments, have been duly considered. In these experiments the dams were reproduced in a small scale.

The adopted run-off curves parallel in the main those of Prof. Le Conte and other investigators, but give slightly greater discharges for depths below 9 feet and smaller discharges above that depth. The greater discharges on low heads have been confirmed by careful computation, and are justified by the conditions and form of the structures. The higher heads are rarely reached in the 23 years' observations. Use of the higher curves would not materially affect the total discharge.

There is no hesitation in the assertion that the curves which have been adopted fairly represent the actual discharges.

All computations for discharge have been carefully checked, and the statement of stream discharges is as accurate as can be made from the data available.

Errors in Discharges Over Dams Due to Single Daily Observations, Eliminated by Compensation in Period of Years.

It may be suggested that run-off deduced from gage heights recorded only once in 24 hours will result in excessive discharge.

Consideration of the records will, however, prove the probability of compensation as shown by the following.

The increase of the floods was generally much more rapid than the decrease. This is well illustrated on several occasions, notably in 1891 and in 1892, when the records of flow at the Niles Dam were as follows:

GAGE HEIGHTS—NILES DAM.

1891.		1892.	
Feb. 22	0′ 6″	Nov. 28	1′ 7″
" 23	6′ 6″	" 29	5′ 7″
" 24	4′ 0″	" 30	9′ 10″
" 25	3′ 0″	Dec. 1	7′ 0″
" 26	2′ 1″	" 2	5′ 6″
" 27	2′ 3″	" 3	8′ 6″
" 28	4′ 8″	" 4	5′ 0″
Mar. 1	7′ 4″	" 5	3′ 6″
" 2	4′ 11″	" 6	3′ 0″
" 3	3′ 5″	" 7	2′ 3″
" 4	2′ 9″		
" 5	1′ 5″		

In both cases, the discharges calculated for the first day, on the depth given for that day, would unquestionably represent a smaller vol-

ume than was discharged during the 24 hours. Most likely the increase began some time during that first day, and would swell the discharge for that day above that due to the gage height shown.

In the case of extremely high discharges continuing for only a few hours, as from "cloud bursts", infrequent measurements might miss the discharge entirely, or if the depth has been taken at the peak flood of the flow, show discharges greatly in excess of the actual run-off. But the record of gage heights show little or no evidence of the occurrence of such torrential floods, the fluctuations being due to normal rise of the stream, following the rains, and marked by a sudden increase of considerable depth.

The discharge for each day has been calculated from the depth of water noted that day, for instance, 6 inches depth on February 22nd, 1891, as in above statement, and not for the average depth of that day and the next succeeding day.

Conditions similar to those quoted in the years 1891 and 1892 prevail more or less accentuated, at the beginning of the period of flood in each year when the gagings were made at the Niles Dam.

As previously stated the notations of gauge heights were more frequently made, especially during flood stages, at the Sunol Dam than at the Niles Dam.

To determine the difference in the results obtained from the daily gage heights and from the varying heights recorded during flood stages, the discharges over the Sunol Dam, from the season 1900-01 to the season 1911-12, inclusive —have been computed, *first* from the fluctuating heights as recorded, in some instances 15 minutes apart, and *second* from the height of gage recorded at 8 a. m. on each day, and the comparative results are shown below:

FLOW OVER SUNOL DAM.

Season.	Computed From Varying Heights M. G.	Computed From 8 a. m. Gage Heights M. G.
1900-01	38,936	40,130
1901-02	25,472	25,051
1902-03	34,945	31,097
1903-04	29,907	29,837
1904-05	14,579	14,579
1905-06	60,565	63,063
1906-07	100,154	98,307
1907-08	14,723	14,957
1908-09	78,002	78,711
1909-10	25,264	24,425
1910-11	87,049	88,056
1911-12	5,043	5,627
Total	514,639	513,840

8 a. m. gage heights—99.8 per cent of varying heights.

The total difference, in these 12 seasons, amounts to 799 million gallons, or 66.6 million gallons per annum, or 182,466 gallons per day *less* by computing from the daily gage heights recorded then from the fluctuating gage heights recording during the floods.

The greatest difference in any one season is in 1902-03, when the result computed from the daily gage heights is *less* than that from the varying heights in a total volume of 3,848 million gallons, or 89 per cent of the volume obtained by the varying heights.

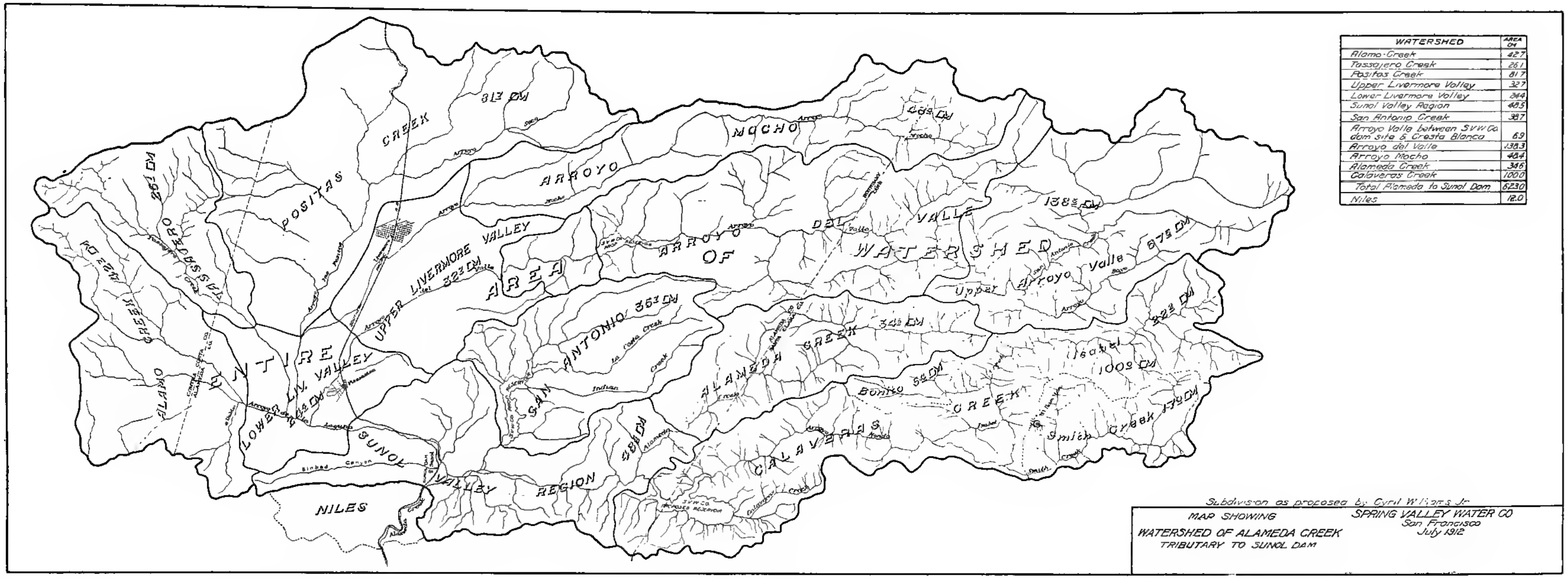
The next greatest difference is in the season 1905-06 when the result computed from the daily gage heights is *more* than that from the varying heights in a total volume of 2,498 million gallons, or 4.12 per cent more than the volume obtained by the varying heights.

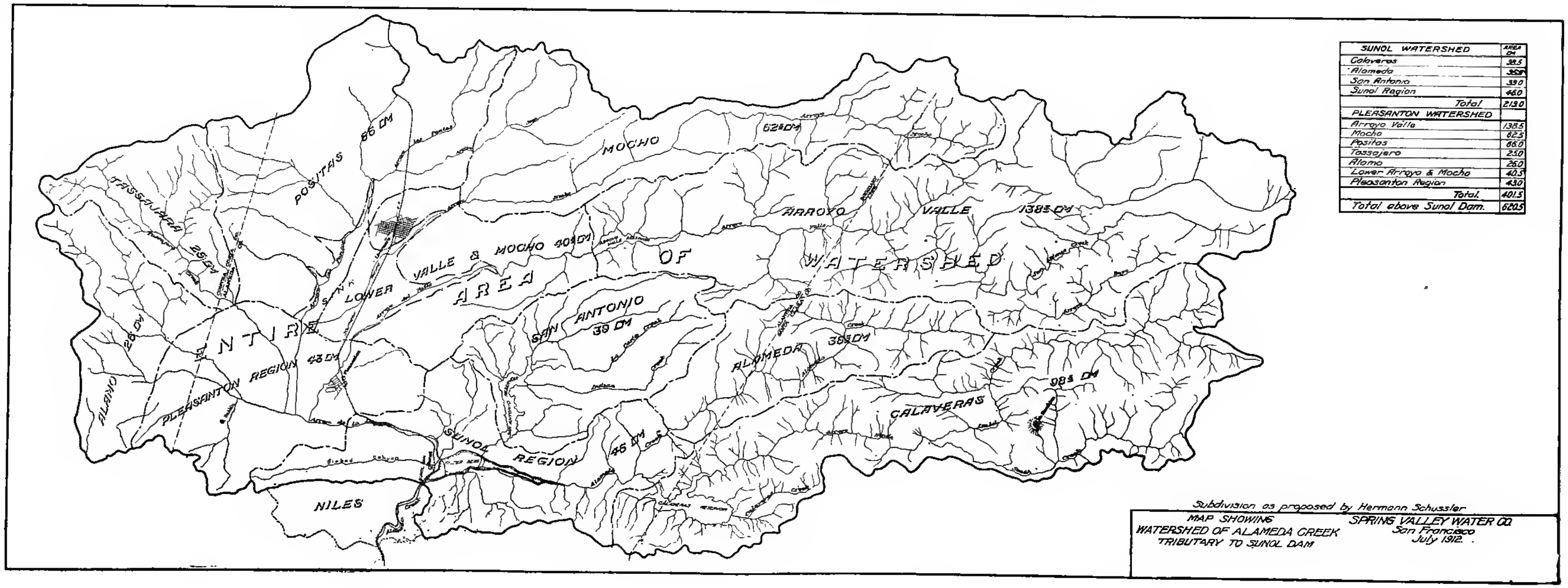
That illustration justifies the conclusion that the quantities obtained by computation of the daily gage heights over the period of years at the Niles Dam will result in a close approximation to the quantities that would have been obtained from more frequent gagings at shorter intervals, that compensation occurs, and that the maximum in any one season will not materially affect the results in that season, and be entirely eliminated in a period of 10 or 12 years.

Present Evaporation Loss From Saturated Soils in Livermore Valley 20 M. G. D.

In some respects the eastern portion of Alameda Creek Drainage Area resembles those water systems that exist in South Central Oregon and elsewhere.

There are in that territory several complete drainage areas that have no outlet to the sea. The streams rise in mountain ranges, and flow some distance, and then discharge into a lake, having no outlet and impervious bottom.


WATERSHED | AREA DM
Alamo Creek | 42.7
Tassajero Creek | 26.1
Positas Creek | 81.7
Upper Livermore Valley | 32.7
Lower Livermore Valley | 24.4
Sunol Valley Region | 48.5
San Antonio Creek | 38.7
Arroyo Valle between S.V.W.Co. dam site & Cresta Blanco | 6.9
Arroyo del Valle | 138.3
Arroyo Mocho | 48.4
Alameda Creek | 34.6
Calaveras Creek | 100.0
Total Alameda to Sunol Dam | 623.0
Niles | 12.0
Subdivision as proposed by Cyril Williams Jr.
MAP SHOWING
WATERSHED OF ALAMEDA CREEK
TRIBUTARY TO SUNOL DAM
SPRING VALLEY WATER CO
San Francisco
July 1912
ENTIRE AREA OF WATERSHED
NILES


SUNOL WATERSHED | AREA DM
Calaveras | 98.5
Alameda |
San Antonio | 39.0
Sunol Region | 46.0
Total | 213.0
PLEASANTON WATERSHED
Arroyo Valle | 138.5
Mocho | 62.5
Positas | 86.0
Tassajero | 25.0
Alamo | 26.0
Lower Arroyo & Mocho | 40.5
Pleasanton Region | 43.0
Total | 401.5
Total above Sunol Dam | 620.5
Subdivision as proposed by Hermann Schussler
MAP SHOWING
WATERSHED OF ALAMEDA CREEK
TRIBUTARY TO SUNOL DAM
SPRING VALLEY WATER CO
San Francisco
July 1912.
ENTIRE AREA OF WATERSHED
NILES

In such water systems, the evaporation losses from the water surface of the lake and river equals the entire observed stream flow. The level of the lakes fluctuate but little from year to year. Some of these rivers carry large volumes of water and drain large areas.

As shown in more detail by Report on Evaporation from Wet Lands in Livermore Valley (page 482) a lake or lagoon has been known to always exist in the lower part of the valley.

On the basis of most recent and accurate tests made, the loss of water by evaporation from this lagoon has been established as averaging 20 to 24 M. G. D. before the drainage works recently put in operation were constructed.

The further loss by evaporation, sustained while the water is flowing in natural channels, from the subdivision points, at which impounding works would be constructed, to Sunol, has not been determined. That loss is considerable and would be largely obviated by the construction of closed conduits conveying the water from the impounding reservoirs. Addition of some volume representing this saving to the estimates of segregated flows could therefore, justly be made. The fact that this has not been done adds a margin of safety to the calculations.

Total Flow From Alameda System, Including Recoverable Losses From Evaporation, Not Less Than 172 to 176 M. G. D.

The total discharge at Sunol for the seasons 1889-90 to 1911-12, amounts to 1,278,890 M. G., giving an average discharge for the 23 seasons of 55,604 M. G. per year, or 152.33 M. G. daily.

In order to determine the total water yield of all the separate drainage areas, the various losses sustained, must be added as not appearing in the volume at Sunol. These are due to evaporation from the saturated areas, to loss in transit, and to local consumption. Of these, evaporation from Pleasanton Lagoon alone amounts to from 20 to 24 million gallons daily.

The tributary stream flow within the drainage area above Sunol must therefore amount to a total of not less than 172 to 176 M. G. daily average flow for the 23 year period. In this is not included loss from river flow and local consumption, which would swell the total of the discharge that could be gaged or measured out of each tributary drainage area.

Flow From Various Tributaries of Alameda Creek Can be Completely Regulated.

The sites for reservoirs and impounding works contemplated for complete regulation of the natural stream flow from season to season and year to year are located on the various tributaries.

The total available regulated flow from the system, will be the sum of the flow delivered in proper conduits from the various parts.

It is therefore necessary, in order to derive conclusions as to the safe yield from the streams, to distribute and segregate the total flow, and apportion the same to the various subdivisions.

These subdivisions are shown on the accompanying maps as proposed by previous investigators. For these investigations subdivision shown on map (page 138) has been used.

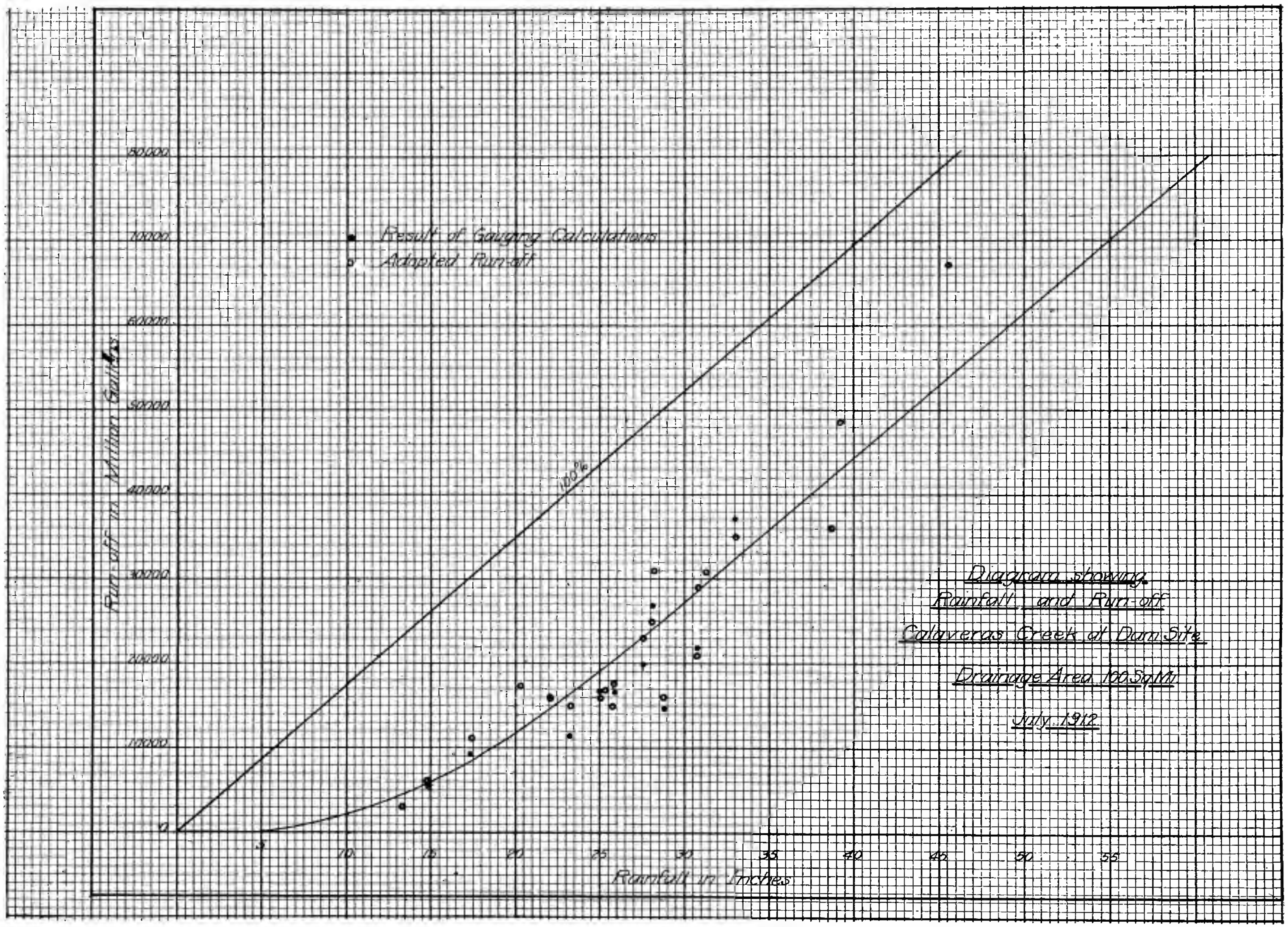
Comparatively little data is available, directly showing the stream flow of tributaries, and a greater number of observations, maintained over a period of years, at gaging stations throughout the various areas would have been desirable.

Available Records Enable Accurate Determination of Contribution of Flow From Various Tributaries.

The period of 23 years during which observations have been made is sufficiently long to embrace, in all probability, the extreme variations of flow.

With the observations available, it is possible by careful study of the rainfall records, the hydrographic characteristics of the areas themselves and the flow at Sunol, to arrive at fairly accurate conclusions of the separate amounts from each tributary, if the losses occurring during the flow of water from the tributaries are borne fully in mind.

Rainfall records for a great number of stations, covering the whole period of observations at each of them, have been prepared after thorough examination of original records (page 445.) No attempt has been made to interpolate or estimate precipitation in seasons for which ob-



THE RELATION BETWEEN RAINFALL AND RUN-OFF AT THE CALAVERAS RESERVOIR WAS DETERMINED BY ACTUAL GAGINGS COVERING 12 SEASONS.

servations are lacking. The records submitted represent only an accurate statement of observed rainfall.

The rainfall tables have been utilized in the distribution of the total run-off among the various drainage areas composing the total watershed. Full consideration has been given to annual, seasonal and monthly differences at the various stations in the immediate vicinity of the drainage areas considered. In general it has not been attempted to build up theoretical curves of run-off from these records of rainfall.

Calaveras Hydrographic Data of Material Assistance in Determination of Run-off.

Calaveras Creek occupies the most important section. While its drainage area is not the largest, it is the most productive of water, by reason of its position and characteristics. It has greater rainfall than any other section.

Rainfall observations within the area have been maintained at Calaveras Damsite since 1874, with the exception of two seasons, and at Lick Observatory, Mount Hamilton, since 1881.

The stream flow was observed continuously from 1898 to 1908, with exception of part of 1905, and subsequently from 1910 to the present time. The work was not very methodical before 1910, but the discharges computed from all of the records obtainable, prove of material assistance in the determination of the relation of the Calaveras run-off to the total Sunol run-off.

In the first period of these observations, extending from 1898-99 to 1903-04, the records vary from depths over a weir, to depths and widths over prescribed lengths of channel. The original notes do not set out the cross section of the stream, but some data in this regard is available in the Spring Valley Water Company files. Careful investigation of all data, shows results that are undoubtedly substantially correct.

The records for the remainder of the period are not so clear, though with care in examination and computation, resulting in many alterations of the results formerly used by the Spring Valley Water Company, volumes that bear a reasonable relation to the rainfall recorded in the various years have been established.

From the stream flow observations, it is evident that run-off commences almost invariably, immediately following an accumulated rainfall of 5 inches.

The observed flow for the season of 1911-12 is reliable. Regular and methodical observations of depth were made, and the discharges are based upon current meter measurements. The observations are of special value as showing a comparatively low yield in a year of next to the lowest rainfall, observed at Calaveras, since 1889.

The above two items provide starting points for the rainfall and run-off curve presented on page 140.

In order to determine the flow each year, the records of rainfall at Calaveras were considered for each season, month by month, and in some instances, daily. To determine the yield, deduction was made of 5 inches at the beginning of each season's precipitation, as the amount required for original saturation, and of 2 inches per month after saturation for evaporation. The balance was considered as "effective" rainfall, and the whole volume, from that precipitation on the entire drainage area, plotted on a diagram. The result was then reviewed, taking into consideration the effect of the rainfall at Mount Hamilton upon the upper, and larger, portion of the drainage area.

The seasonal flow thus obtained for the whole period was compared with the volume of flow calculated from the observations from 1898 to 1908. These calculated stream flows, together with the run-offs adopted in each year, and the corresponding rainfall are shown on the Diagram of Rainfall and Run-off. (Page 140.)

Run-off Varies With Meteorological Conditions.

The investigatious show a difference in run-off, from the same or approximately the same total rainfall. This is inevitable, and would be experienced, due to the different intensity of the rainfall in the various periods.

The great run-off in 1889-90, with the greatest rainfall, 45.5 inches, is readily accounted for by consideration of the rainfall record for that season. After two months of more than average rain (9.60 inches total), follow two months with a precipitation exceeding 10 inches in each month, and following them again, two

months of more than average precipitation (9.19 inches total). The conditions result in excessive saturation and extreme readiness to flow.

The large volume of the observed flow in the season of 1906-07 may be explained on similar conditions. In that season of comparatively high rainfall (32.98 inches at Calaveras), practically 65 per cent of the total effective rainfall occurred in one month, March, preceded by one month of rainfall just above the allowance for evaporation and preceeding that, two months of excessive precipitation (14.44 inches). In addition to these conditions, the rainfall at Mount Hamilton during that season was 30 per cent in excess of that at Calaveras, being 43.34 inches for the season. The maximum monthly rainfall at Mount Hamilton occurred in the same month, March, as at Calaveras.

As the results of all the considerations closely agree, the conclusion is inevitable that the volumes of run-off adopted for each year at Calaveras must correctly represent the discharge of the stream. They will afford a reasonable foundation for apportioning the remaining volume of the total Sunol run-off to the other divisions of the tributary area.

Determination of Run-off From Upper Alameda Creek.

The only data available for comparison of the run-off of the Upper Alameda Creek with that of Calaveras Creek, or with the total Sunol run-off, consist of observations of flow from March, 1911, to the present time. The flow has been established by current meter measurements.

For the period preceding July, 1911, these observations show a run-off of 29.4 per cent of the Calaveras Creek run-off. For the period from July, 1911, to June, 1912, the run-off is 31 per cent of Calaveras. The relation is, naturally, one of marked variations. The dry season flow of Upper Alameda Creek is low, actually and comparatively receding to 5.43 million gallons for the month of October, 1911; and during that period the percentage falls as low as from 5 to 11 per cent. During the period of high flow the percentage increases, ranging from 20 to 39 per cent.

The hydrographic conditions of Upper Alameda Creek differ from those of Calaveras Creek in some respects. All conditions indicate the probability of slightly reduced rainfall, due to topographic features and position of the area in relation to the direction of prevailing winds. Soil conditions are such that a reduced run-off would result from the same rainfall. Altogether the conclusion would be that, from the same rainfall, the run-off per square mile from Upper Alameda drainage area would be about 70 per cent of the Calaveras Creek run-off. As the Upper Alameda area is 34.6 per cent of the Calaveras area, this would result in a total slightly in excess of 24 per cent.

In distributing the total Sunol flow, it has been assumed that the contribution from Upper Alameda Creek is 25 per cent of the total run-off of Calaveras Creek.

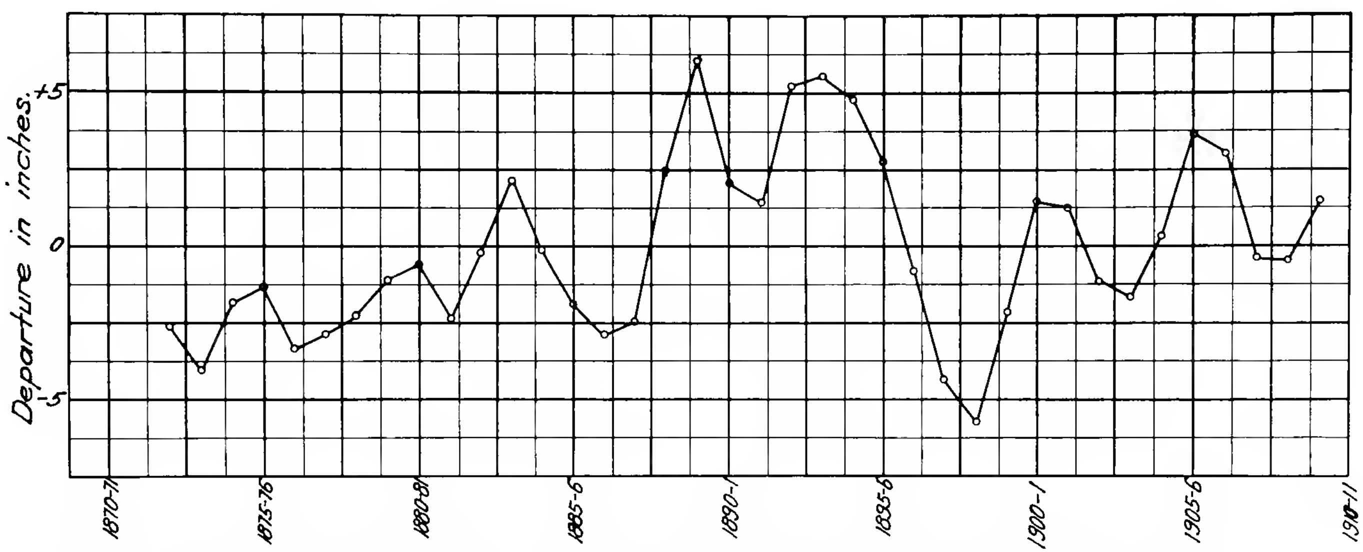
From this general rule, one exception must be noted, the season of 1889-90. Reference has already been made to the intensity of the rainfall in that season, and it is believed that the conditions leading to an excessive run-off for Calaveras Creek area would exist on Upper Alameda Creek area. For that season, the run-off per square mile on the Upper Alameda Creek is considered to be the same as from Calaveras Creek.

Results From Run-off Curve for San Antonio Conform in Variation to Run-off at Sunol Dam.

For the San Antonio Creek drainage area there are neither rainfall observations, nor stream measurements available.

The western and upper part of the area would undoubtedly be affected by a rainfall similar to that of the Calaveras drainage, though undoubtedly reduced, as the clouds, passing over the high ridges enclosing the Calaveras area, are stripped of the greater part of their moisture. The rainfall in the lower and eastern section of the area, would probably more nearly approach the precipitation in the Livermore Valley.

The soil conditions in the San Antonio area are not quite so favorable to effective run-off as Calaveras, indicating somewhat greater absorption. On the other hand, the run-off conditions of Calaveras would more nearly govern than those of the Livermore Valley.



Mean Annual Precipitation at Livermore from 1872 to 1911 is 15.81 inches.

DIAGRAM-1

SEASONAL PRECIPITATION

AT

LIVERMORE

Expression as Departures of Three-year Progressive Averages from Normal.

THE DEPARTURE OF SEASONAL RAINFALL FROM THE NORMAL IS SHOWN GRAPHICALLY.

After thorough consideration, the rainfall as recorded at Livermore, applied to the run-off curve for Calaveras was adopted as applicable, and the adopted amounts varied in relation to the general proportion of the total Sunal run-off, as these vary from season to season.

Run-off per Square Mile From Sunol Area and Sinbad Creek Resembles San Antonio.

In the Sunol area, rainfall observations have been maintained at Sunol for the whole period of 23 years.

Using the same method as for Calaveras, that is, making deduction, first for original saturation, and monthly thereafter for evaporation, but altering the amounts to 8 and 3 inches respectively, total seasonal run-offs are obtained, bearing reasonable relation to the run-off per square mile in the other areas.

The results show run-offs per square mile which, on the whole, resemble those of the San Antonio area. Topographical conditions and general characteristics indicate the probability of a better yield.

Hydrographic Data at Arroyo Valle Indicates Conditions of Its Stream Discharge.

The data available for Arroyo Valle are confined to rainfall records and stream flow observations for only four seasons, 1904-05 to 1907-08.

The results from the flow observations are shown in the tabulation of Arroyo Valle gaging. (Page 478.)

The records are not complete for any entire season, although the main periods of flow no doubt were those to be recorded. The calculated flow, therefore, must be taken as indicative of general conditions of stream discharge, rather than as showing the exact amount of water.

The conclusion is inevitable that the lower section of the area will be affected by a rainfall similar to that at Livermore, and the upper section by a rainfall as at Mount Hamilton, or rather by that rainfall somewhat reduced in volume. On both sections, the run-off will be governed by conditions differing from Calaveras.

The areas considered are, first, that part of Arroyo Valle, lying above the reservoir site, and second, that part below as shown by the two divisions indicated on the map. (Page 138.)

For the lower area, the rainfall at Livermore was adopted and distributed for each season on the basis of 8 inches for original saturation, and 3 inches per month evaporation. For the upper area, the Mount Hamilton rainfall reduced 10 per cent was adopted and distributed on the same basis as in the other area.

The preliminary results were checked against run-off from all remaining sections of the area tributary above Sunol. Taking the rainfall at Livermore and calculating the run-off by first deducting 8 inches for complete saturation and 3 inches per month, subsequently for evaporation, results were derived that, with some modifications due to local and seasonal variations, compared closely with the results obtained for Arroyo Valle Creek. They confirm the conclusion that Arroyo Valle yields approximately one-half of the total run-off from the upper area outside of Calaveras, Upper Alameda, San Antonio and Sunol-Sinbad areas. The proportion varies with the seasons and the intensity of the rainfall.

Run-off From Livermore Valley Indicates Greater Loss From Evaporation Than Other Tributaries.

The method of determination of run-off from Livermore Valley follows the lines set out in the preceding pages.

The rainfall at Livermore was adopted for the whole area and run-off calculated deducting first 8 inches for saturation, and subsequently 3 inches per month for evaporation.

This method will frequently show a lack of run-off from a greater rainfall than 8 inches, or even 11 inches, and will as frequently show lack of run-off for dry years. This is believed to be consistent with the actual conditions.

The flow from the whole area was distributed to the various portions of the Livermore Valley in direct relation to their areas, with the exception of Arroyo Mocho.

Run-off per Square Mile From Arroyo Mocho Nearly 60 per Cent of Run-off per Square Mile From Arroyo Valle.

The Arroyo Mocho area was considered as

bearing to the Arroyo Valle approximately the same relation as Upper Alameda does to Calaveras, probably with a lower percentage of run-off per square mile, being more nearly 60 per cent than 70 per cent of the Arroyo Valle run-off.

The final findings, showing the segregated flow from each of the tributaries, are assembled in the Tabulation of Segregated Flow. (Page 146.)

The sum total of all segregated flows amount to 163.29 M. G. D.

In the chapter of Total Flow has been shown that the sum of flow at Sunol, and loss by evaporation from water in transit, corresponds to a total flow from tributaries of 172 to 176 M. G. D.

The results of the segregation studies are therefore low and conservative. In view of the entirely different methods by which the two results have been derived, the conclusions agree remarkably well.

TABULATION OF SEGREGATED FLOW FROM THE VARIOUS DRAINAGE AREAS OF TOTAL ALAMEDA CREEK DRAINAGE AREA.

Year.	Calaveras 100 Sq. Mi. M. G.	Upper Alameda 34.6 Sq. Mi. M. G.	San Antonio 38.7 Sq. Mi. M. G.	Sunol 48.5 Sq. Mi. M. G.	Arroyo Valle 138.3 Sq. Mi. M. G.	Arroyo Mocha 48.4 Sq. Mi. M. G.	Lower Arroyo Valle 6.9 Sq. Mi. M. G.	Upper Livermore 32.7 Sq. Mi. M. G.	Lower Livermore 24.4 Sq. Mi. M. G.	Positas Creek 81.7 Sq. Mi. M. G.	Tassajero 26.1 Sq. Mi. M. G.	Alamo Creek 42.7 Sq. Mi. M. G.	Total. M. G.
1889-90	67,000	23,182	14,900	14,162	31,054	6,534	885	4,230	3,180	10,500	3,320	5,528	184,475
1890-91	17,206	4,301	2,581	276	9,000	1,888	227	1,090	816	2,700	852	1,421	42,358
1891-92	17,000	4,250	2,550	873	4,200	.....	...	.....	.....	.....	.....	.....	28,873
1892-93	48,600	12,150	7,300	4,600	25,000	5,227	536	2,562	1,925	6,370	2,012	3,360	119,642
1893-94	29,000	7,250	4,350	4,656	13,612	2,856	340	1,654	1,240	4,120	1,298	2,163	72,539
1894-95	36,000	9,000	5,400	7,760	21,000	4,356	470	2,250	1,690	5,600	1,766	2,940	98,232
1895-96	17,570	4,392	2,636	3,540	7,230	1,500	205	975	735	2,430	767	1,275	43,255
1896-97	30,608	7,652	4,591	4,365	14,000	2,904	360	1,715	1,291	4,270	1,350	2,246	75,352
1897-98	3,000	750	450	170	1,200	.....	...	.....	.....	.....	.....	.....	5,570
1898-99	16,000	4,000	2,400	3,880	5,100	.....	...	.....	.....	.....	.....	.....	31,380
1899-00	15,000	3,750	2,250	1,698	4,400	.....	...	.....	.....	.....	.....	.....	27,098
1900-01	21,000	5,250	3,150	3,880	8,800	1,840	193	923	694	2,295	725	1,210	49,960
1901-02	15,000	3,750	2,250	3,150	6,000	1,258	156	744	560	1,850	584	972	36,274
1902-03	16,000	4,000	2,400	3,880	10,000	2,080	269	1,288	968	3,200	1,010	1,685	46,780
1903-04	23,000	5,750	3,450	5,044	4,400	920	54	260	195	646	205	340	44,264
1904-05	16,000	4,000	2,400	2,280	2,500	484	5	26	20	66	21	35	27,837
1905-06	25,000	6,250	3,750	5,820	12,000	2,520	296	1,420	1,070	3,525	1,113	1,856	64,620
1906-07	35,000	8,750	5,250	8,245	28,000	5,810	700	3,325	2,505	8,280	2,620	4,360	112,845
1907-08	11,000	2,750	1,650	2,352	4,800	1,016	93	440	332	1,096	346	577	26,452
1908-09	33,000	8,250	4,950	7,663	18,000	3,775	455	2,175	1,635	5,405	1,710	2,845	89,863
1909-10	12,500	3,125	1,875	2,668	8,000	1,694	80	380	285	950	300	511	32,368
1910-11	31,000	7,750	4,650	8,633	22,000	4,645	525	2,500	1,880	6,215	1,965	3,270	95,033
1911-12	6,000	1,500	900	335	3,500	720	90	420	315	1,060	340	555	15,735
Totals	541,484	141,802	86,083	99,930	263,796	52,027	5,939	28,377	21,336	70,578	22,304	37,149	1,370,805
Av. per annum	23,543	6,165	3,743	4,345	11,469	2,262	258	1,234	928	3,069	969	1,615	59,600
Av. per day	64.50	16.89	10.26	11.90	31.42	6.19	.70	3.39	2.54	8.41	2.66	4.42	163.28

TABULATION OF THE COMPARISON OF RUN-OFF PER SQUARE MILE ON VARIOUS DRAINAGE AREAS INCLUDED IN TOTAL ALAMEDA CREEK DRAINAGE AREA FROM SEGREGATED FLOW.

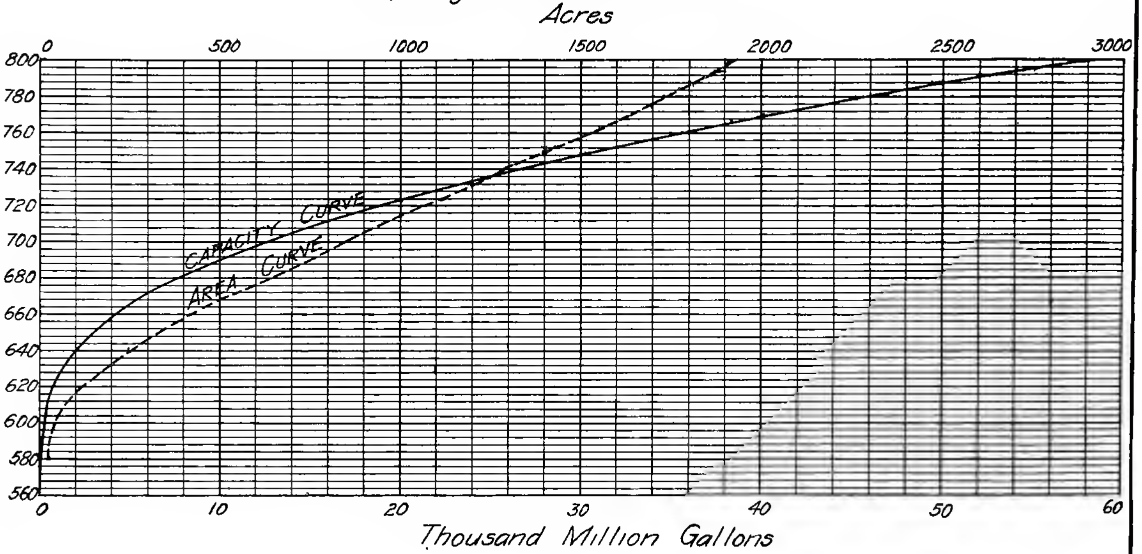
Years.	Calaveras rainfall.	Calaveras run-off, M. G.	Upper Alameda run-off, M. G.	San Antonio run-off, M. G.	Sunol Area rainfall.	Sunol Area run-off, M. G.	Arroyo Valle rainfall.	Arroyo Valle run-off, M. G.	Livermore rainfall.	Arroyo Mocho run-off, M. G.	Lower Arroyo V. run-off, M. G.	Upper Livermore run-off, M. G.	Lower Livermore run-off, M. G.	Positas run-off, M. G.	Tassajero run-off, M. G.	Alamo run-off, M. G.
1889-90	45.5″	670	670	385	39.0″	292	.....	224	28.7″	135	128	129.4	130	128.5	127.2	129.4
1890-91	20.2″	172	124	67	14.0″	5.7	.....	65	14.2″	39	33	33.3	33.4	32.7	32.6	33.3
1891-92	25.2″	170	124	67	16.5″	18	.....	30	14.2″	...	.....	.....	.....	.....	.....	.....
1892-93	39.2″	486	350	189	27.2″	95	.....	180	26.3″	108	77.8	78.3	78.8	78.0	77.1	78.7
1893-94	30.8″	290	210	112	21.7″	96	.....	98	17.2″	59	49.3	50.6	50.8	50.4	49.7	50.7
1894-95	38.6″	360	260	139	27.0″	160	.....	151	24.4″	90	68.1	68.8	69.3	68.5	67.7	68.8
1895-96	25.8″	176	124	68	17.6″	73	.....	52	16.4″	31	29.5	30.0	30.0	29.7	29.3	30.0
1896-97	31.2″	306	221	118	22.2″	90	.....	101	17.3″	60	52.2	52.4	52.9	52.3	51.7	52.4
1897-98	13.4″	30	21	12	10.5″	3.5	.....	9	9.1″	...	.....	.....	.....	.....	.....	....
1898-99	22.0″	160	115	62	16.3″	80	.....	37	9.3″	...	.....	.....	.....	.....	.....	....
1899-00	25.8″	150	108	58	22.3″	35	.....	32	12.7″	...	.....	.....	.....	.....	.....	....
1900-01	30.7″	210	150	81	25.4″	80	.....	64	19.7″	38	28	28.2	28.4	28.1	27.7	28.3
1901-02	23.3″	150	108	58	19.5″	64	.....	43	16.8″	26	22.6	22.7	22.9	22.6	22.4	22.7
1902-03	25.0″	160	115	62	19.0″	80	.....	72	14.3″	43	39.0	39.2	39.7	39.1	38.7	39.4
1903-04	27.5″	230	166	90	22.2″	104	.....	32	13.3″	19	7.8	8.0	8.0	7.9	7.9	8.0
1904-05	28.7″	160	115	62	23.3″	47	.....	18	15.8″	10	.7	.8	.8	.8	.8	.8
1905-06	28.0″	250	180	96	25.2″	120	20.8″	87	19.3″	52	43	43.4	44.1	43.1	42.6	43.5
1906-07	33.0″	350	250	136	29.8″	170	26.8″	202	23.1″	120	101.4	101.7	102.2	101.3	100.4	102.1
1907-08	17.3″	110	80	42	16.2″	48.5	.....	35	9.9″	21	13.5	13.4	13.6	13.4	13.2	13.5
1908-09	.....	330	240	128	25.1″	158	.....	130	18.6″	78	66	66.5	67.0	66.2	65.5	66.6
1909-10	.....	125	90	48	18.5″	55	.....	58	14.5″	35	11.6	11.6	11.7	11.6	11.6	11.9
1910-11	28.1″	310	224	120	28.4″	222	.....	159	21.3″	96	76	76.4	77.0	76.0	75.3	76.5
1911-12	14.8″	60	43	23	15.8″	6.9	.....	25.3	9.6″	15	13	1:	13	13	13	13

CALAVERAS RESERVOIR

Capacity and Area.

Contour Elevation	Area in Acres	Capacity in M.G.
560	0.37	0.00
580	11.2	37.70
600	33.7	183.93
620	123.8	697.67
640	261.0	1951.70
660	418.0	4165.78
680	643.0	7623.41
700	845.0	12474.19
720	1078.0	18744.30
740	1291.0	26465.53
760	1531.0	35 665.93
780	1736.0	46 315.58
800	1930.0	58 257.40

Crest of Dam - Elev. 800'
Max. Water Height - Elev. 795'
Capacity - 55,000,000,000 Gals.



Calculations from Map F-81

Crystal Springs Datum.

From Records of S.V.W.Co.
Drawn by A.J.Krutmeyer S.V.W.Co.
Compared & Checked by H. Mouritt S.V.W.Co.

SPRING VALLEY WATER CO.
San Francisco.
July - 1912

Anderson C-1

CALAVERAS RESERVOIR WILL BE ONE OF THE LARGEST IN THE WEST.

REGULATED FLOW FROM ALAMEDA SYSTEM.

In order to arrive at a conclusion of the safe daily yield from the whole Alameda System it is necessary to consider what regulated flow can be drawn from the various subdivisions and the method required in each case to regulate the flow. In the previous chapter has been shown the tributary stream flow of the subdivisions.

Regulated Flow From Calaveras Reservoir.

Calaveras Reservoir will be supplied by the natural flow of Calaveras Creek, together with diverted flow of Upper Alameda Creek.

It is proposed to construct the dam to elevation 800, with a highwater line at elevation 780. At that latter elevation, the storage capacity of the reservoir will be 46,315 million gallons. The storage capacity at elevation 795, or 5 feet below the crest of the dam, will be 55,000 million gallons, or an addition of 8,685 million gallons; this will be regarded as reserve storage capacity.

In the following derivation of regulated flow from the two streams a capacity of 46,315 million gallons only is first considered. Excess flow is then noted, and regulated by additional storage as subsequently commented upon.

With a dam constructed on Calaveras Creek, all of the waters of that Creek would be available for storage. This might not be true of the peak floods of the Upper Alameda Creek, as these might be in excess of the transporting capacity of the diversion canal to be constructed, connecting Upper Alameda with Calaveras Reservoir.

Good judgment must be exercised in determining the dimensions of the diversion canal. This is specially true, as the knowledge of extreme floods is not too extensive at this time.

There is to be noted a peak flood of 51 million gallons per day per square mile on the Upper Alameda Creek in 1906, equivalent to, approximately, 79 cubic feet per second per square mile, or about 2,730 cubic feet per second from the whole area of 34.6 square miles. There is no record of the duration of this flood.

The later continuous measurements of Upper Alameda Creek from 1910 to the present time show a maximum flood occurring in March, 1911, with a discharge of 2,341-8 million gallons in 24 hours or 3,625 cubic feet per second with about one half of that volume on the preceding and about one-fifth of it on the following day.

With an aqueduct, preferably a tunnel, of ordinary capacity, say from 1,500 to 2,000 cubic feet per second, there would, doubtless, be occasions at long intervals, when for a short period, the peak of the flood might be lost. Some of that loss could be prevented by making the diversion dam of some height, not so much for the purpose of creating a small storage in Upper Alameda Creek itself, as for increasing the head on the tunnel during short periods of flood.

At any rate, the amount of loss incurred would be a very small percentage of the total volume in any year, and, in a long period, would probably not amount to 1 per cent of the total flow.

The following tables (pages 151-155), showing the distribution of the combined Calaveras and Upper Alameda Creek flows over the whole period from 1889 to the present time, are largely self-explanatory.

The total flows previously developed in the general distribution have been distributed monthly, in proportion to the total Sunol runoff.

The table assumes the reservoir empty at the beginning and a continued draft of 57 million gallons daily.

Evaporation has been deducted monthly, on the basis of a total of 4 feet per annum, distributed on ratios shown in the accompanying report on evaporation. (Page 482.)

Nothing has been added on account of the saving caused by the seasonal rainfall falling on the water surface of the reservoir. This would be a total gain, and could be fairly added to the final results.

From the first analysis of these tables it is evident that, from the combined flow of Calaveras and Upper Alameda Creek, a daily discharge of 57 million gallons could be secured and that there would be stored at the end of the period, 26,866 million gallons. There would also be a surplus of 145,312 million gallons.

The lowest storage reached is 7,116 million gallons at the beginning of February, 1904.

But, as shown later, there were still 8,685 million gallons in reserve at Calaveras Reservoir and 3,150 million gallons in reserve at Crystal Springs Reservoir, a total of 18,951 million gallons, or slightly over 90 per cent of one year's supply on a daily consumption of 57 million gallons. This condition was immediately preceding the season of run-off.

The lowest storage at the beginning of any dry season is 16,989 millions gallons, at the first of July, 1903. At that time there were 8,685 million gallons in reserve at Calaveras Reservoir, and 9,600 million gallons in reserve at Crystal Springs Reservoir, a total of 35,274 million gallons. This is 1 year and 8 months supply on a daily consumption of 57 million gallons.

In order to regulate, as far as possible, the surplus of 145,312 million gallons, part would be held by the additional storage capacity in the Calaveras Reservoir of 8,685 million gallons, from the water line of elevation 780 to the line 5 feet below the crest elevation 800, or elevation 795, and part would be diverted to Crystal Springs Reservoir through an aqueduct to be constructed with a capacity of 250 million gallons per day, Crystal Springs Dam to be raised and capacity increased.

In view of the large volume of the floods, it is entirely possible that some portion of this surplus of 145,312 million gallons would be wasted. The capacity of the Crystal Springs conduit might not be large enough to transport both the daily draft and the excess waters as they came. With the best judgment exercised in the limitation of the dimensions of that conduit, it might not be economical to attempt to conserve all of that flow.

The following table showing conservation of the surplus is based on a conduit capacity of 250 million gallons per day, conveying, *first,* 57 M. G. D., as the daily draft, and, *second,* its full capacity beyond that to Crystal Springs Reservoir, any quantity beyond the combined amount of 250 M. G. D. being considered waste.

The tabulation shows that, of the total, 145,312 million gallons, 123,249 million gallons can be conserved corresponding to 14.67 M. G. D. for 23 years additional to the daily draft of 57 M. G. D., and that 22,063 million gallons or 2.63 M. G. D. would be wasted. (Page 156.)

CALAVERAS RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 57 M. G. D.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft. for month. M. G.	Re-mainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evapora-tion for month, feet.	Evapora-tion loss for month, M. G.	Total at end of month, M. G.	In reser-voir, M. G.	Sur-plus, M. G.
					1889-90.							
July	.....	.....	.....	....	....	....	....	....	....	....	....	....
August	.....	.....	...	....	....	....	....	....	....	....	....	....
September	.....	.....	.....	....	....	....	....	....	....	....	....	....
October	.....	.....	.....	....	....	....	....	....	....	....	....	....
November	.....	.....	.....	....	....	....	....	....	....	....	....	....
December	.....	19,911	19,911	1,767	18,144	1,055	528	.08	14	18,130	18,130	....
January	18,130	37,666	55,796	1,767	54,029	1,736	1,395	.08	36	53,993	46,315	7,678
February	46,315	17,951	64,266	1,596	62,670	1,736	1,736	.08	45	62,625	46,315	16,310
March	46,315	10,205	56,520	1,767	54,753	1,736	1,736	.20	113	54,640	46,315	8,325
April	46,315	2,499	48,814	1,710	47,104	1,736	1,736	.28	158	46,946	46,315	631
May	46,315	1,400	47,715	1,767	45,943	1,728	1,732	.40	226	45,722	45,722	....
June	45,722	550	46,272	1,710	44,562	1,700	1,714	.56	313	44,249	44,249	....
					1890-91.							
July	44,249	390	44,639	1,767	42,872	1,672	1,686	.68	374	42,498	42,498	....
August	42,498	336	42,834	1,767	41,067	1,636	1,654	.64	345	40,722	40,722	....
September	40,722	305	41,027	1,710	39,317	1,603	1,620	.56	296	39,021	39,021	....
October	39,021	317	39,338	1,767	37,571	1,570	1,587	.28	145	37,426	37,426	....
November	37,426	317	37,743	1,710	36,033	1,541	1,556	.16	81	35,952	35,952	....
December	35,952	625	36,577	1,767	34,810	1,509	1,525	.08	40	34,770	34,770	....
January	34,770	670	35,440	1,767	33,673	1,480	1,495	.08	39	33,634	33,634	....
February	33,634	7,473	41,107	1,596	39,511	1,608	1,544	.08	40	39,471	39,471	....
March	39,471	8,400	47,871	1,767	46,104	1,734	1,671	.20	109	45,995	45,995	....
April	45,995	1,540	47,535	1,710	45,825	1,728	1,731	.28	158	45,667	45,667	....
May	45,667	704	46,371	1,767	44,604	1,705	1,716	.40	224	44,380	44,380	....
June	44,380	430	44,810	1,710	43,100	1,677	1,691	.56	308	42,792	42,792	....
					1891-92.							
July	42,792	405	43,197	1,767	41,430	1,644	1,660	.68	368	41,062	41,062	....
August	41,062	205	41,267	1,767	39,500	1,608	1,626	.64	339	39,161	39,161	....
September	39,161	175	39,336	1,710	37,626	1,572	1,590	.56	290	37,336	37,336	....
October	37,336	170	37,506	1,767	35,739	1,537	1,554	.28	142	35,597	35,597	....
November	35,597	163	35,760	1,710	34,050	1,492	1,514	.16	79	33,971	33,971	....
December	33,971	3,390	37,361	1,767	35,594	1,531	1,512	.08	39	35,555	35,555	....
January	35,555	1,726	37,281	1,767	35,514	1,531	1,531	.08	40	35,474	35,474	....
February	35,474	1,786	37,260	1,653	35,607	1,531	1,531	.08	40	35,567	35,567	....
March	35,567	6,200	41,767	1,767	40,000	1,615	1,573	.20	103	39,897	39,897	....
April	39,897	4,000	43,897	1,710	42,187	1,659	1,637	.28	150	42,037	42,037	....
May	42,037	2,400	44,437	1,767	42,670	1,666	1,663	.40	218	42,452	42,452	....
June	42,452	630	43,082	1,710	41,372	1,643	1,655	.56	302	41,070	41,070	....
					1892-93.							
July	41,070	170	41,240	1,767	39,473	1,605	1,624	.68	360	39,113	39,113	....
August	39,113	90	39,203	1,767	37,436	1,566	1,586	.64	331	37,105	37,105	....
September	37,105	60	37,165	1,710	35,455	1,529	1,547	.56	282	35,173	35,173	....
October	35,173	60	35,233	1,767	33,466	1,489	1,509	.28	138	33,328	33,328	....
November	33,328	8,330	41,658	1,710	39,948	1,615	1,552	.16	81	39,867	39,867	....
December	39,867	23,840	63,707	1,767	61,940	1,736	1,676	.08	44	61,896	46,315	15,581
January	46,315	7,385	53,700	1,767	51,933	1,736	1,736	.08	45	51,888	46,315	5,573
February	46,315	13,120	59,435	1,596	57,839	1,736	1,736	.08	45	57,794	46,315	11,479
March	46,315	3,245	49,560	1,767	47,793	1,736	1,736	.20	113	47,680	46,315	1,365
April	46,315	2,970	49,285	1,710	47,575	1,736	1,736	.28	158	47,417	46,315	1,102
May	46,315	1,210	47,525	1,767	45,758	1,726	1,731	.40	226	45,532	45,532	....
June	45,532	270	45,802	1,710	44,092	1,693	1,710	.56	312	43,780	43,780	....
					1893-94.							
July	43,780	260	44,040	1,767	42,273	1,670	1,682	.68	373	41,900	41,900	....
August	41,900	200	42,100	1,767	40,333	1,620	1,645	.64	343	39,990	39,990	....
September	39,990	140	40,130	1,710	38,420	1,584	1,602	.56	292	38,128	38,128	....
October	38,128	100	38,228	1,767	36,461	1,547	1,566	.28	143	36,318	36,318	....
November	36,318	140	36,458	1,710	34,748	1,505	1,526	.16	80	34,668	34,668	....
December	34,668	270	34,938	1,767	33,171	1,466	1,486	.08	39	33,132	33,132	....
January	33,132	9,690	42,822	1,767	41,055	1,636	1,551	.08	40	41,015	41,015	....
February	41,015	22,010	63,025	1,596	61,429	1,736	1,686	.08	44	61,385	46,315	15,070
March	46,315	2,290	48,605	1,767	46,838	1,736	1,736	.20	113	46,725	46,315	410
April	46,315	560	46,875	1,710	45,165	1,715	1,725	.28	157	45,008	45,008	....
May	45,008	350	45,358	1,767	43,591	1,693	1,704	.40	222	43,369	43,369	....
June	43,369	240	43,609	1,710	41,899	1,649	1,671	.56	305	41,594	41,594	....

CALAVERAS RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 57 M. G. D.—Cont'd.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft. for month. M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
1894-95.												
July	41,594	142	41,736	1,767	39,969	1,613	1,631	.68	362	39,607	39,607	....
August	39,607	88	39,695	1,767	37,928	1,574	1,594	.64	332	37,596	37,596	....
September	37,596	77	37,673	1,710	35,963	1,540	1,557	.56	284	35,679	35,679	....
October	35,679	116	35,795	1,767	34,028	1,489	1,514	.28	138	33,890	33,890	....
November	33,890	55	33,945	1,710	32,235	1,441	1,465	.16	76	32,159	32,159	....
December	32,159	9,138	41,297	1,767	39,530	1,615	1,528	.08	40	39,490	39,490	....
January	39,490	25,157	64,647	1,767	62,880	1,736	1,676	.08	44	62,836	46,315	16,521
February	46,315	6,532	52,847	1,596	51,251	1,736	1,736	.08	45	51,206	46,315	4,891
March	46,315	1,575	47,890	1,767	46,123	1,728	1,732	.20	113	46,010	46,010	....
April	46,010	1,065	47,075	1,710	45,365	1,717	1,722	.28	157	45,208	45,208	....
May	45,208	805	46,013	1,767	44,246	1,695	1,706	.40	222	44,024	44,024	....
June	44,024	250	44,274	1,710	42,564	1,664	1,680	.56	306	42,258	42,258	....
1895-96.												
July	42,258	147	42,405	1,767	40,638	1,628	1,646	.68	365	40,273	40,273	....
August	40,273	140	40,413	1,767	38,646	1,587	1,608	.64	335	38,311	38,311	....
September	38,311	138	38,449	1,710	36,739	1,551	1,569	.56	286	36,453	36,453	....
October	36,453	189	36,642	1,767	34,875	1,509	1,530	.28	140	34,735	34,735	....
November	34,735	190	34,925	1,710	33,215	1,469	1,489	.16	78	33,137	33,137	....
December	33,137	220	33,357	1,767	31,590	1,423	1,446	.08	38	31,552	31,552	....
January	31,552	11,270	42,822	1,767	41,055	1,633	1,528	.08	40	41,015	41,015	....
February	41,015	1,114	42,129	1,653	40,476	1,624	1,628	.08	42	40,434	40,434	....
March	40,434	1,182	41,616	1,767	39,849	1,613	1,618	.20	105	39,744	39,744	....
April	39,744	5,672	45,416	1,710	43,706	1,687	1,650	.28	150	43,556	43,556	....
May	43,556	1,370	44,926	1,767	43,159	1,677	1,682	.40	219	42,940	42,940	....
June	42,940	330	43,270	1,710	41,560	1,649	1,663	.56	304	41,256	41,256	....
1896-97.												
July	41,256	225	41,481	1,767	39,714	1,608	1,628	.68	361	39,353	39,353	....
August	39,353	185	39,538	1,767	37,771	1,572	1,590	.64	332	37,439	37,439	....
September	37,439	185	37,624	1,710	35,914	1,536	1,554	.56	284	35,630	35,630	....
October	35,630	205	35,835	1,767	34,068	1,489	1,512	.28	138	33,930	33,930	....
November	33,930	920	34,850	1,710	33,140	1,465	1,477	.16	77	33,063	33,063	....
December	33,063	1,425	34,488	1,767	32,721	1,453	1,459	.08	38	32,683	32,683	....
January	32,683	1,465	34,148	1,767	32,381	1,447	1,450	.08	38	32,343	32,343	....
February	32,343	14,730	47,073	1,596	45,477	1,720	1,584	.08	41	45,436	45,436	....
March	45,436	15,400	60,836	1,767	59,069	1,736	1,728	.20	112	58,957	46,315	12,642
April	46,315	2,540	48,855	1,710	47,145	1,736	1,736	.28	158	46,987	46,315	672
May	46,315	705	47,020	1,767	45,253	1,715	1,726	.40	225	45,028	45,028	....
June	45,028	275	45,303	1,710	43,593	1,684	1,700	.56	310	43,283	43,283	....
1897-98.												
July	43,283	205	43,488	1,767	41,721	1,648	1,666	.68	370	41,351	41,351	....
August	41,351	204	41,555	1,767	39,788	1,611	1,630	.64	340	39,448	39,448	....
September	39,448	189	39,637	1,710	37,927	1,574	1,592	.56	290	37,637	37,637	....
October	37,637	210	37,847	1,767	36,080	1,539	1,556	.28	142	35,938	35,938	....
November	35,938	170	36,108	1,710	34,398	1,495	1,517	.16	79	34,319	34,319	....
December	34,319	115	34,434	1,767	32,667	1,453	1,474	.08	38	32,629	32,629	....
January	32,629	194	32,823	1,767	31,056	1,411	1,432	.08	37	31,019	31,019	....
February	31,019	920	31,939	1,596	30,343	1,393	1,402	.08	37	30,306	30,306	....
March	30,306	700	31,006	1,767	29,239	1,363	1,378	.20	90	29,149	29,149	....
April	29,149	355	29,504	1,710	27,794	1,327	1,345	.28	123	27,671	27,671	....
May	27,671	270	27,941	1,767	26,174	1,280	1,304	.40	170	26,004	26,004	....
June	26,004	218	26,222	1,710	24,512	1,237	1,258	.56	230	24,282	24,282	....
1898-99.												
July	24,282	145	24,427	1,767	22,660	1,186	1,212	.68	270	22,390	22,390	....
August	22,390	115	22,505	1,767	20,738	1,130	1,158	.64	241	20,497	20,497	....
September	20,497	120	20,617	1,710	18,907	1,083	1,106	.56	201	18,706	18,706	....
October	18,706	170	18,876	1,767	17,109	1,019	1,051	.28	95	17,014	17,014	....
November	17,014	170	17,184	1,710	15,474	955	987	.16	50	15,424	15,424	....
December	15,424	175	15,599	1,767	13,832	895	925	.08	23	13,809	13,809	....
January	13,809	465	14,274	1,767	12,507	845	870	.08	22	12,485	12,485	....
February	12,485	195	12,680	1,596	11,084	784	814	.08	20	11,064	11,064	....
March	11,064	16,960	28,024	1,767	26,257	1,285	1,034	.20	66	26,191	26,191	....
April	26,191	915	27,106	1,710	25,396	1,260	1,272	.28	115	25,281	25,281	....
May	25,281	335	25,616	1,767	23,849	1,217	1,238	.40	161	23,688	23,688	....
June	23,688	235	23,923	1,710	22,213	1,172	1,194	.56	218	21,995	21,995	....

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 57 M. G. D.—Cont'd.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft for month. M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
1899-1900.												
July	21,995	285	22,280	1,767	20,513	1,127	1,150	.68	255	20,258	20,258	....
August	20,258	265	20,523	1,767	18,756	1,078	1,103	.64	230	18,526	18,526	....
September	18,526	255	18,781	1,710	17,071	1,019	1,048	.56	191	16,880	16,880	....
October	16,880	265	17,145	1,767	15,378	950	984	.28	90	15,288	15,288	....
November	15,288	620	15,908	1,710	14,198	909	930	.16	48	14,150	14,150	....
December	14,150	1,890	16,040	1,767	14,273	911	910	.08	24	14,249	14,249	....
January	14,249	10,480	24,729	1,767	22,962	1,195	1,053	.08	27	22,935	22,935	....
February	22,935	750	23,685	1,596	22,089	1,167	1,181	.08	31	22,058	22,058	....
March	22,058	2,240	24,298	1,767	22,531	1,183	1,176	.20	77	22,454	22,454	....
April	22,454	830	23,284	1,710	21,574	1,154	1,168	.28	106	21,468	21,468	....
May	21,468	560	22,028	1,767	20,261	1,120	1,137	.40	148	20,113	20,113	....
June	20,113	310	20,423	1,710	18,713	1,078	1,099	.56	201	18,512	18,512	....
1900-01.												
July	18,512	160	18,672	1,767	16,905	1,008	1,043	.68	231	16,674	16,674	....
August	16,674	155	16,829	1,767	15,062	948	978	.64	204	14,858	14,858	....
September	14,858	150	15,008	1,710	13,298	880	914	.56	167	13,131	13,131	....
October	13,131	275	13,406	1,767	11,639	819	849	.28	77	11,562	11,562	....
November	11,562	5,150	16,712	1,710	15,002	944	882	.16	46	14,956	14,956	....
December	14,956	765	15,721	1,767	13,954	903	923	.08	24	13,930	13,930	....
January	13,930	4,020	17,950	1,767	16,183	985	944	.08	25	16,158	16,158	....
February	16,158	11,175	27,333	1,596	25,737	1,275	1,130	.08	29	25,708	25,708	....
March	25,708	2,155	27,863	1,767	26,096	1,282	1,278	.20	83	26,013	26,013	....
April	26,013	925	26,938	1,710	25,228	1,259	1,270	.28	116	25,112	25,112	....
May	25,112	870	25,982	1,767	24,215	1,232	1,245	.40	162	24,053	24,053	....
June	24,053	450	24,503	1,710	22,793	1,195	1,213	.56	221	22,572	22,572	....
1901-02.												
July	22,572	318	22,890	1,767	21,123	1,146	1,170	.68	259	20,864	20,864	....
August	20,864	238	21,102	1,767	19,335	1,099	1,122	.64	234	19,101	19,101	....
September	19,101	192	19,293	1,710	17,583	1,043	1,071	.56	196	17,387	17,387	....
October	17,387	193	17,580	1,767	15,813	974	1,018	.28	92	15,721	15,721	....
November	15,721	200	15,921	1,710	14,211	909	942	.16	49	14,162	14,162	....
December	14,162	440	14,602	1,767	12,835	856	882	.08	32	12,803	12,803	....
January	12,803	215	13,018	1,767	11,251	796	826	.08	22	11,229	11,229	....
February	11,229	5,742	16,971	1,596	15,375	954	875	.08	23	15,352	15,352	....
March	15,352	8,500	23,852	1,767	22,085	1,171	1,062	.20	69	22,016	22,016	....
April	22,016	1,592	23,608	1,710	21,898	1,168	1,170	.28	107	21,791	21,791	....
May	21,791	730	22,521	1,767	20,754	1,135	1,152	.40	150	20,604	20,604	....
June	20,604	390	20,994	1,710	19,284	1,094	1,115	.56	204	19,080	19,080	....
1902-03.												
July	19,080	225	19,305	1,767	17,538	1,043	1,068	.68	237	17,301	17,301	....
August	17,301	240	17,541	1,767	15,774	969	1,006	.64	210	15,564	15,564	....
September	15,564	145	15,709	1,710	13,999	905	937	.56	171	13,828	13,828	....
October	13,828	158	13,986	1,767	12,219	826	866	.28	79	12,140	12,140	....
November	12,140	207	12,347	1,710	10,637	767	797	.16	42	10,595	10,595	....
December	10,595	200	10,795	1,767	9,028	701	734	.08	19	9,009	9,009	....
January	9,009	3,495	12,504	1,767	10,737	771	736	.08	19	10,718	10,718	....
February	10,718	2,850	13,568	1,596	11,972	825	798	.08	21	11,951	11,951	....
March	11,951	5,865	17,816	1,767	16,049	977	901	.20	59	15,990	15,990	....
April	15,990	5,625	21,615	1,710	19,905	1,111	1,044	.28	95	19,810	19,810	....
May	19,810	675	20,485	1,767	18,718	1,078	1,094	.40	142	18,576	18,576	....
June	18,576	315	18,891	1,710	17,181	1,022	1,050	.56	192	16,989	16,989	....
1903-04.												
July	16,989	485	17,474	1,767	15,707	965	994	.68	220	15,487	15,487	....
August	15,487	375	15,862	1,767	14,095	905	935	.64	195	13,900	13,900	....
September	13,900	305	14,205	1,710	12,495	845	875	.56	160	12,335	12,335	....
October	12,335	275	12,610	1,767	10,843	775	810	.28	74	10,769	10,769	....
November	10,769	660	11,429	1,710	9,719	730	752	.16	39	9,680	9,680	....
December	9,680	460	10,140	1,767	8,373	676	703	.08	18	8,355	8,355	....
January	8,355	545	8,900	1,767	7,133	611	644	.08	17	7,116	7,116	....
February	7,116	6,550	13,666	1,653	12,013	824	718	.08	19	11,994	11,994	....
March	11,994	12,400	24,394	1,767	22,627	1,185	1,004	.20	65	22,562	22,562	....
April	22,562	4,340	26,902	1,710	25,192	1,256	1,220	.28	111	25,081	25,081	....
May	25,081	1,760	26,841	1,767	25,074	1,253	1,254	.40	163	24,911	24,911	....
June	24,911	595	25,506	1,710	23,796	1,217	1,235	.56	225	23,571	23,571	....

CALAVERAS RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 57 M. G. D.—Cont'd.

1904-05.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft. for month. M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
July	23,571	542	24,113	1,767	22,346	1,177	1,197	.68	265	22,081	22,081	....
August	22,081	460	22,541	1,767	20,774	1,135	1,156	.64	241	20,533	20,533	....
September	20,533	345	20,878	1,710	19,168	1,092	1,114	.56	203	18,965	18,965	....
October	18,965	369	19,334	1,767	17,567	1,037	1,064	.28	97	17,470	17,470	....
November	17,470	384	17,854	1,710	16,144	980	1,008	.16	53	16,091	16,091	....
December	16,091	617	16,708	1,767	14,941	935	958	.08	25	14,916	14,916	....
January	14,916	1,508	16,424	1,767	14,657	928	932	.08	24	14,633	14,633	....
February	14,633	3,906	18,539	1,596	16,943	1,008	968	.08	25	16,918	16,918	....
March	16,918	6,916	23,834	1,767	22,067	1,167	1,088	.20	71	21,996	21,996	....
April	21,996	2,307	24,303	1,710	22,593	1,185	1,176	.28	107	22,486	22,486	....
May	22,486	1,985	24,471	1,767	22,704	1,190	1,188	.40	155	22,549	22,549	....
June	22,549	661	23,210	1,710	21,500	1,154	1,172	.56	214	21,286	21,286	....

1905-06.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft. for month. M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
July	21,286	240	21,526	1,767	19,759	1,108	1,131	.68	251	19,508	19,508	....
August	19,508	205	19,713	1,767	17,946	1,048	1,078	.64	225	17,721	17,721	....
September	17,721	135	17,856	1,710	16,146	980	1,014	.56	185	15,961	15,961	....
October	15,961	125	16,086	1,767	14,319	913	946	.28	85	14,234	14,234	....
November	14,234	115	14,349	1,710	12,639	849	881	.16	46	12,593	12,593	....
December	12,593	135	12,728	1,767	10,961	783	816	.08	21	10,940	10,940	....
January	10,940	8,145	19,085	1,767	17,318	1,025	904	.08	24	17,294	17,294	....
February	17,294	3,710	21,004	1,596	19,408	1,097	1,061	.08	28	19,380	19,380	....
March	19,380	12,135	31,515	1,767	29,748	1,374	1,236	.20	81	29,667	29,667	....
April	29,667	4,365	34,032	1,710	32,322	1,444	1,409	.28	128	32,194	32,194	....
May	32,194	1,220	33,414	1,767	31,647	1,424	1,434	.40	187	31,460	31,460	....
June	31,460	720	32,180	1,710	30,470	1,395	1,410	.56	257	30,213	30,213	....

1906-07.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft. for month. M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
July	30,213	267	30,480	1,767	28,713	1,351	1,373	.68	304	28,409	28,409	....
August	28,409	205	28,614	1,767	26,847	1,299	1,325	.64	276	26,571	26,571	....
September	26,571	198	26,769	1,710	25,059	1,253	1,276	.56	233	24,826	24,826	....
October	24,826	180	25,006	1,767	23,239	1,201	1,227	.28	112	23,127	23,127	....
November	23,127	170	23,297	1,710	21,587	1,154	1,178	.16	61	21,526	21,526	....
December	21,526	2,670	24,196	1,767	22,429	1,179	1,166	.08	30	22,399	22,399	....
January	22,399	8,780	31,179	1,767	29,412	1,367	1,273	.08	33	29,379	29,379	....
February	29,379	3,622	33,001	1,596	31,405	1,423	1,395	.08	36	31,369	31,369	....
March	31,369	23,035	54,404	1,767	52,637	1,736	1,580	.20	103	52,534	46,315	6,219
April	46,315	3,045	49,360	1,710	47,650	1,736	1,736	.28	158	47,492	46,315	1,177
May	46,315	1,025	47,340	1,767	45,573	1,722	1,729	.40	225	45,348	45,348	....
June	45,348	553	45,901	1,710	44,191	1,695	1,708	.56	312	43,879	43,879	....

1907-08.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft. for month. M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
July	43,879	731	44,610	1,767	42,843	1,669	1,682	.68	373	42,470	42,470	....
August	42,470	513	42,983	1,767	41,216	1,639	1,654	.64	345	40,871	40,871	....
September	40,871	365	41,236	1,710	39,526	1,605	1,622	.56	296	39,230	39,230	....
October	39,230	366	39,596	1,767	37,829	1,572	1,589	.28	145	37,684	37,684	....
November	37,684	463	38,147	1,710	36,437	1,545	1,558	.16	81	36,356	36,356	....
December	36,356	1,281	37,637	1,767	35,870	1,535	1,540	.08	40	35,830	35,830	....
January	35,830	3,126	38,956	1,767	37,189	1,560	1,548	.08	40	37,149	37,149	....
February	37,149	2,812	39,961	1,653	38,308	1,581	1,570	.08	41	38,267	38,267	....
March	38,267	2,475	40,742	1,767	38,975	1,595	1,588	.20	104	38,871	38,871	....
April	38,871	715	39,586	1,710	38,876	1,574	1,584	.28	144	37,732	37,732	....
May	37,732	558	38,290	1,767	36,523	1,547	1,560	.40	203	36,320	36,320	....
June	36,320	345	36,665	1,710	34,955	1,513	1,530	.56	279	34,676	34,676	....

1908-09.

	Stored at first of month, M. G.	Inflow for month. M. G.	Total for month. M. G.	Draft. for month. M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
July	34,676	265	34,941	1,767	33,174	1,466	1,490	.68	330	32 844	32,844	....
August	32,844	210	33,054	1,767	31,287	1,416	1,441	.64	301	30,986	30,986	....
September	30,986	180	31,166	1,710	29,456	1,369	1,392	.56	254	29,202	29,202	....
October	29,202	160	29,362	1,767	27,595	1,320	1,344	.28	123	27,472	27,472	....
November	27,472	160	27,632	1,710	25,922	1,275	1,298	.16	68	25,854	25,854	....
December	25,854	180	26,034	1,767	24,267	1,231	1,253	.08	33	24,234	24,234	....
January	24,234	17,850	42,084	1,767	40,317	1,620	1,426	.08	37	40,280	40,280	....
February	40,280	15,905	56,185	1,596	54,589	1,736	1,678	.08	44	54,545	46,315	8,230
March	46,315	4,615	50,930	1,767	49,163	1,736	1,736	.20	113	49,050	46,315	2,735
April	46,315	960	47,275	1,710	45,565	1,721	1,728	.28	158	45,407	45,407	....
May	45,407	435	45,842	1,767	44,075	1,694	1,707	.40	222	43,853	43,853	....
June	43,853	330	44,183	1,710	42,473	1,662	1,678	.56	306	42,167	42,167	....

CALAVERAS RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 57 M. G. D.—Con'td.

	Stored at first of month, M. G.	Inflow for month, M. G.	Total for month, M. G.	Draft for month, M. G.	Remainder, M. G.	Surface area end of month, acres.	Average area, acres.	Evaporation for month, feet.	Evaporation loss for month, M. G.	Total at end of month, M. G.	In reservoir, M. G.	Surplus, M. G.
1909-10.												
July	42,167	300	42,467	1,767	40,700	1,628	1,645	.68	365	40,335	40,335	....
August	40,335	245	40,580	1,767	38,813	1,592	1,610	.64	336	38,477	38,477	....
September	38,477	240	38,717	1,710	37,007	1,557	1,574	.56	287	36,720	36,720	....
October	36,720	275	36,995	1,767	35,228	1,518	1,538	.28	140	35,088	35,088	....
November	35,088	250	35,338	1,710	33,628	1,476	1,497	.16	78	33,550	33,550	....
December	33,550	1,710	35,260	1,767	33,493	1,474	1,475	.08	38	33,455	33,455	....
January	33,455	5,400	38,855	1,767	37,088	1,558	1,516	.08	40	37,048	37,048	....
February	37,048	2,255	39,303	1,596	37,707	1,570	1,564	.08	41	37,666	37,666	....
March	37,666	2,805	40,471	1,767	38,704	1,589	1,580	.20	103	38,601	38,601	....
April	38,601	1,245	39,846	1,710	38,136	1,577	1,583	.28	144	37,992	37,992	....
May	37,992	570	38,562	1,767	36,795	1,552	1,564	.40	204	36,591	36,591	....
June	36,591	330	36,921	1,710	35,211	1,518	1,535	.56	280	34,931	34,931	....
1910-11.												
July	34,931	240	35,171	1,767	33,404	1,471	1,494	.68	331	33,073	33,073	....
August	33,073	225	33,298	1,767	31,531	1,421	1,446	.64	302	31,229	31,229	....
September	31,229	180	31,409	1,710	29,699	1,374	1,398	.56	255	29,444	29,444	....
October	29,444	100	29,544	1,767	27,777	1,327	1,350	.28	123	27,654	27,654	....
November	27,654	135	27,789	1,710	26,079	1,277	1,302	.16	68	26,011	26,011	....
December	26,011	195	26,206	1,767	24,439	1,234	1,256	.08	33	24,406	24,406	....
January	24,406	12,695	37,101	1,767	35,334	1,521	1,378	.08	36	35,298	35,298	....
February	35,298	5,200	40,498	1,596	38,902	1,593	1,557	.08	41	38,861	38,861	....
March	38,861	18,030	56,891	1,767	55,124	1,736	1,664	.20	108	55,016	46,315	8,701
April	46,315	985	47,300	1,710	45,590	1,722	1,729	.28	158	45,432	45,432	....
May	45,432	480	45,912	1,767	44,145	1,695	1,708	.40	222	43,923	43,923	....
June	43,923	285	44,208	1,710	42,498	1,662	1,678	.56	306	42,192	42,192	....
1911-12.												
July	42,192	388	42,580	1,767	40,813	1,630	1,646	.68	366	40,447	40,447	....
August	40,447	416	40,863	1,767	39,096	1,597	1,613	.64	336	38,760	38,760	....
September	38,760	339	39,099	1,710	37,389	1,565	1,581	.56	289	37,100	37,100	....
October	37,100	372	37,472	1,767	35,705	1,531	1,548	.28	141	35,564	35,564	....
November	35,564	387	35,951	1,710	34,241	1,492	1,512	.16	79	34,162	34,162	....
December	34,162	413	34,575	1,767	32,808	1,455	1,474	.08	38	32,770	32,770	....
January	32,770	907	33,677	1,767	31,910	1,432	1,444	.08	38	31,872	31,872	....
February	31,872	698	32,570	1,653	30,917	1,406	1,419	.08	37	30,880	30,880	....
March	30,880	2,084	32,964	1,767	31,197	1,414	1,410	.20	92	31,105	31,105	....
April	31,105	717	31,822	1,710	30,112	1,385	1,400	.28	128	29,984	29,984	....
May	29,984	439	30,423	1,767	28,656	1,349	1,367	.40	178	28,478	28,478	....
June	28,478	340	28,818	1,710	27,108	1,307	1,328	.56	242	26,866	26,866	....

CALAVERAS RESERVOIR.

DISTRIBUTION OF EXCESS FLOW.

At high water line, 780.00 feet, capacity is 46,315 M. G.

At maximum water line—795.00 feet (5 feet below crest) capacity is 55,000 M. G., providing additional storage of 8,685 M. G.

Increase of Crystal Springs Reservoir gives conditions as follows:

Present water line 288.00 feet—capacity 23,500 M. G.

Ultimate water line—323.00 feet—capacity 55,000 M. G., providing additional storage of 31,500 M. G.

It is proposed to connect these reservoirs by conduit of 250 M. G. D. capacity.

	Calaveras Reservoir Surplus M. G.		Calaveras Reservoir Additional Capacity M. G.		Crystal Springs Additional Capacity M. G.		Lost M. G.
1889-90.							
January	7,678		7,678				
February	16,310		1,007		5,404		9,899
March	8,325				5,983		2,342
April	631				631		
		32,944		8,685		12,018	
1892-93.							
December	15,581		8,685		5,983		913
January	5,573				5,573		
February	11,479				5,404		6.075
March	1,365				1,365		
April	1,102				1,102		
		35,100		8,685		19,427	
1893-94.							
February	15,070		8,685		5,404		981
March	410				410		
		15,480		8,685		5,814	
1894-95.							
January	16,521		8,685		5,983		1,853
February	4,891				4,891		
		21,412		8,685		10,874	
1896-97.							
March	12,642		8,685		3,957		
April	672				672		
		13,314		8,685		4,629	
1906-07.							
March	6,219		6,219				
April	1,177		1,177				
		7,396		7,396			
1908-09.							
March	8,230		8,230				
April	2,735		455		2,280		
		10,965		8,685		2,280	
1910-11.							
March	8,701		8,685		16		
		8,701		8,685		16	
Total		145,312		68,191		55,058	22,063

NOTE.—The excess flow from Calaveras to Crystal Springs is carried at the rate of 250 M. G. D.—less 57 M. G. D.

The total surplus for 23 years from Calaveras Reservoir is 145,312 M. G.; of this 123,249 M. G. are available for storage, equivalent to 14.67 M. G. D. and 22,063 M. G., escape as waste, equivalent to 2.63 M. G. D.

As is subsequently shown, of the total 123,249 M. G. available for storage, 39,885 M. G. would be used in the equalization of the Gravel Reservoir, leaving 83,364 M. G. directly available for storage, equivalent to 3,625 M. G. per annum for the period of 23 years, and a daily yield of 9.93 M. G., which latter figure is finally used.

Regulated Flow From San Antonio Reservoir.

It is proposed to build the San Antonio Dam 140 feet high to an elevation of 450 feet. The reservoir would have a maximum capacity of 10,500 million gallons at elevation 445 feet, giving five feet freeboard. The water surface, at high water line will have an area of approximately 620 acres.

Treating the total flow from San Antonio drainage in the same manner as shown for Calaveras Reservoir the results shown on the accompanying table are obtained.

The table commences at the beginning of the season 1897-98, assuming a full reservoir. This is justified by review of the annual discharges prior to that time.

The table has been built upon annual discharges as sufficiently indicative of the result. It must be borne in mind that it would not be necessary to maintain a constant draft from San Antonio. When operating Alameda Creek System as a whole, it would be essential to treat San Antonio Reservoir merely as a regulating or equalizing reservoir, to hold flood waters at such time as the discharges from the Sunol-Sinbad Creek areas would produce water to fill the Sunol filter beds and the total capacity of the conduit commencing at Sunol. When this flow recedes only sufficient water would be withdrawn for the capacity of the Sunol filters.

The tabulation shows a safe yield of 8.5 million gallons per day, with a balance in storage at the end of the period, equivalent to over 7 months' draft of 8.5 M. G. D.

Regulated Flow From Sunol Area and Sinbad Creek.

Of the total flow from this area, a large proportion would, at first consideration, appear to be waste, because it is a direct, unregulated flow. The Sunol filter beds cannot be regarded as a storage reservoir. But regulation could be arranged by using San Antonio Reservoir, conserving the floods from that area, and also by regulation of the pumpage flow from Livermore Valley area. That latter feature would to some extent be governed by the advisability of keeping the storage in both San Antonio and Arroyo Valle Reservoirs as low as possible, and the water in the gravel reservoir depressed, in order to provide room for and retain all flood waters.

For the aqueduct leading out of Sunol a capacity of not less than 100 M. G. D. should be provided. As before stated, Calaveras water will be diverted directly from that reservoir and not reach Sunol; the Sunol aqueduct should therefore carry from gravel reservoir, 30 M. G. D.; Arroyo Valle Reservoir, 18 M. G. D.; San Antonio Reservoir, 8.5 M. G. D.; evaporation, 12 M. G. D.; total, 68.5 M. G. D., to which

SAN ANTONIO RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 8.5 M. G. D.

	Stored at First of Season. M. G.	Inflow for Season. M. G.	Total for Season. M. G.	Draft M. G.	Remainder. M. G.	Surface Area. Acres.	Average Area. Acres.	Evaporation Loss. M. G.	Stored at End of Season. M. G.
1897-98	10,500	450	10,950	3,102	7,848	542	584	761	7,087
1898-99	7,087	2,400	9,487	2,840 (a)	6,647	475	508	661	5,986
1899-00	5,986	2,250	8,236	3,102	5,134	407	441	575	4,559
1900-01	4,559	3,150	7,709	2,865 (b)	4,844	398	403	525	4,319
1901-02	4,319	2,250	6,569	2,864 (c)	3,705	335	366	477	3,228
1902-03	3,228	2,400	5,628	2,840 (d)	2,788	278	306	399	2,389
1903-04	2,389	3,450	5,839	2,664 (e)	3,175	302	290	378	2,797
1904-05	2,797	2,400	5,197	3,103	2,094	233	268	349	1,745
1905-06	1,745	3,750	5,495	2,575 (f)	2,920	286	260	339	2,581
1906-07	2,581	5,250	7,831	3,103	4,728	389	338	440	4,288
1907-08	4,288	1,650	5,938	2,839 (g)	3,099	297	343	447	2,652
1908-09	2,652	4,950	7,602	2,600 (h)	5,002	402	350	456	4,546
1909-10	4,546	1,875	6,421	3,103	3,318	311	356	464	2,854
1910-11	2,854	4,650	7,504	2,575 (i)	4,929	399	355	463	4,466
1911-12	4,466	900	5,366	3,103	2,263	244	322	420	1,843

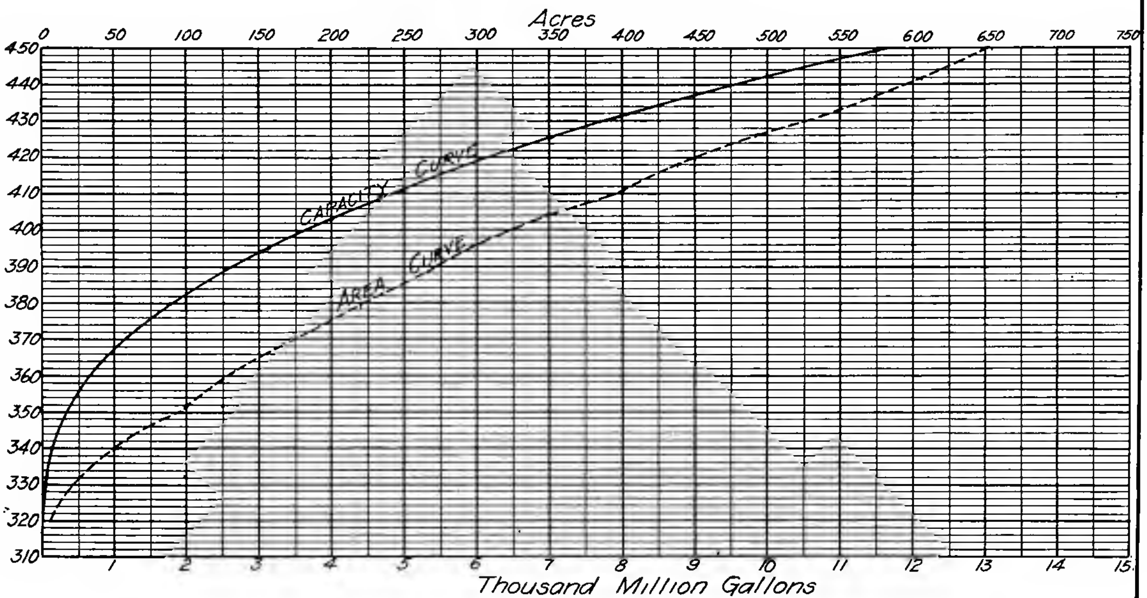
(a) Direct flow from Sunol-Sinbad Creek Area in March, saved all draft that month.
(b) Direct flow from Sunol-Sinbad Creek Area in February, saved all draft that month.
(c) Direct flow from Sunol-Sinbad Creek Area in February, saved all draft that month.
(d) Direct flow from Sunol-Sinbad Creek Area in March, saved all draft that month.
(e) Direct flow from Sunol-Sinbad Creek Area in February and March, saved 438 M. G. draft in these months.
(f) Direct flow from Sunol-Sinbad Creek Area in January and March, saved all draft in these months.
(g) Direct flow from Sunol-Sinbad Creek Area in January, saved all draft in this month.
(h) Direct flow from Sunol-Sinbad Creek Area in January and February, saved all draft in these months.
(i) Direct flow from Sunol-Sinbad Creek Area in January and March, saved all draft in these months.

San Antonio Reservoir

Capacity and Area

Contour Elevation	Area in Acres	Capacity in M.G.
310	0.0	0.0
320	6.2	10.1
330	21.4	55.0
340	45.0	163.3
350	84.0	373.0
360	128.0	712.0
370	176.5	1208.1
380	222.8	1934.1
390	269.9	2661.4
400	331.6	3641.4
410	394.1	4823.7
420	453.6	6204.8
430	529.7	7806.9
440	594.2	9638.0
450	656.0	11674.9

Crest of Dam - Elev. 450'
Max Water Height - Elev. 445
Capacity - 10,500,000,000 Gals



Calculations from Map F-53

Datum = Elevation shown minus 6.76' = C.S.El.

From Records of S.V.W. Co.
Drawn by A.J. Kcutmeyer S.V.W.Co.
Compared & Checked by H. Munitt S.V.W.Co.

Spring Valley Water Co
San Francisco
July - 1912

Anderson C-2

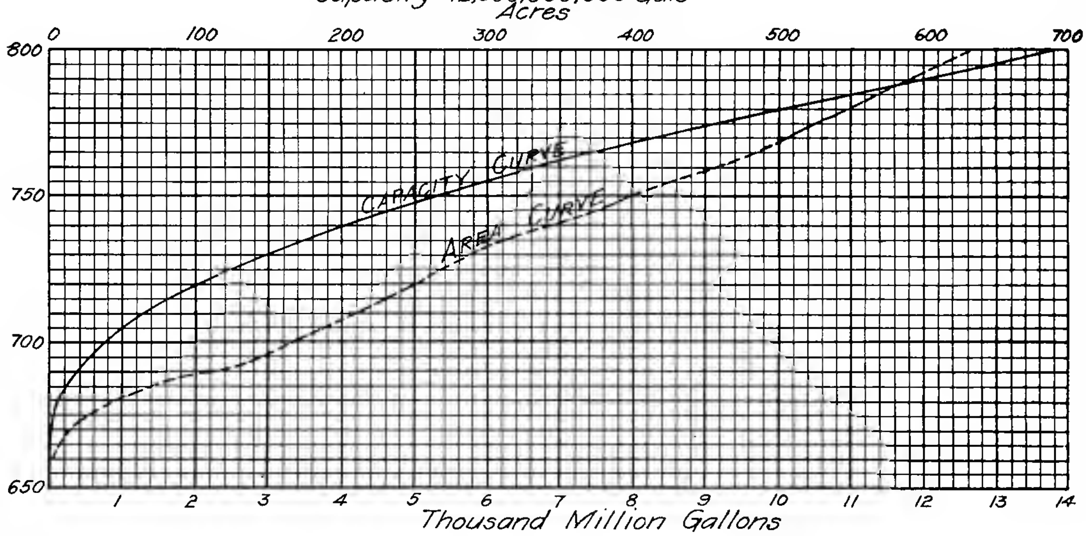
This Reservoir is close to Sunol Gravels and will be used in conjunction with them.

ARROYO VALLE RESERVOIR

Capacity and Area.

Contour Elevation	Area in Acres	Capacity in M.G.
650	0.00	0.0
660	1.98	3.0
670	12.89	27.4
680	39.37	112.4
690	109.00	364.0
700	166.00	792.0
710	207.00	1380.0
720	248.00	2110.0
730	285.00	3085.0
740	346.00	4050.0
750	400.00	5290.0
760	457.00	6690.0
770	506.00	8310.0
780	547.00	10040.0
790	585.00	11910.0
800	630.00	13830.0

Crest of Dam - Elev. 800'
Max Water Height - Elev. 795'
Capacity - 12,900,000,000 Gals



Calculations from Map F 50

Crystal Springs Datum.

From Records of S.V.W.Co.

Drawn by A.J. Krutmeyer S.V.W.Co.

Compared & Checked by H. Mouritt S.V.W.Co.

SPRING VALLEY WATER CO.
San Francisco
July - 1912

Anderson C-3

This Reservoir is just above Livermore Valley and will regulate all the floods of Arroyo Valle and permit their gradual absorption by the gravels below.

about 50 per cent should be added for peak demands. In time of flood the total capacity of 100 M. G. D. would be available, to carry away storm-flow from the area.

Examining the records of estimated monthly flow, and segregating and discarding the volumes exceeding a daily discharge of 100 M. G. D., the following volumes are found available for the system, from the direct stream-flow of the Sunol-Sinbad Creek area:

	M. G.
1889-90	8,490
1890-91	284
1891-92	748
1892-93	4,637
1893-94	5,900
1894-95	5,900
1895-96	3,600
1896-97	4,442
1897-98	180
1898-99	3,100
1899-00	1,690
1900-01	2,800
1901-02	3,087
1902-03	3,911
1903-04	5,270
1904-05	2,336
1905-06	6,264
1906-07	4,480
1907-08	2,380
1908-09	6,018
1909-10	2,720
1910-11	6,213
1911-12	327
	84,777

For the period of 23 years this gives an average yield of 3,686 M. G. per year, or a daily yield of 10.10 M. G. from Sunol-Sinbad Creek areas. The total flow averages 11.90 M. G. D., showing a waste of 15.12 per cent. This natural, utilized flow will be equalized from Arroyo Valle and the Gravel Reservoir, in addition to the regulation by San Antonio Reservoir, already mentioned.

Regulated Flow From Arroyo Valle Reservoir.

It is proposed to build the Arroyo Valle Dam 150 feet high, to an elevation of 800 feet. The reservoir will have a maximum storage capacity of 12,900 million gallons, at elevation 795 feet, giving 5 feet freeboard. The water surface at high water line will have an area of approximately 607 acres.

Treating the total flow estimated for the Arroyo Valle drainage in the same manner as in the other drainage areas, the result obtained is shown in the accompanying table.

In this case, as at Calaveras, the table commences at the beginning of the season 1889-90, assuming the reservoir empty at that time. The tabulation has been built up on annual in place of monthly discharges, as sufficiently indicative of the result.

In this case, as with San Antonio Reservoir, this basin is treated as an equalizing or regulating reservoir, in connection with operation of the Gravel Reservoir in Livermore Valley. The stream flow of the Arroyo Valle Creek would be retained during the period of maximum flow, or when the flow from the other areas tributary to the Gravel Reservoir were sufficient to keep the latter fully supplied. At other seasons, the

ARROYO VALLE RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 18 M. G. D.

	Stored at First of Season. M. G.	Inflow for Season. M. G.	Total for Season. M. G.	Draft for Season. M. G.	Remainder. M. G.	Surface Area. Acres.	Average Area. Acres.	Evaporation Loss. M. G.	Stored at End of Season. M. G.	In Reservoir. M. G.	Surplus. M. G.
1889-90	0	31,054	31,054	6,570	24,484	607	304	158	24,326	12,900	11,426
1890-91	12,900	9,000	21,900	6,570	15,330	607	607	791	14,539	12,900	1,639
1891-92	12,900	4,200	17,100	6,588	10,512	557	582	758	9,754	9,754	....
1892-93	9,754	25,000	34,754	6,570	28,184	607	582	758	27,426	12,900	14,526
1893-94	12,900	13,612	26,512	6,570	19,942	607	607	791	19,151	12,900	6,251
1894-95	12,900	21,000	33,900	6,570	27,330	607	607	791	26,539	12,900	13,639
1895-96	12,900	7,230	20,130	6,588	13,542	607	607	791	12,751	12,751	....
1896-97	12,751	14,000	26,751	6,570	20,181	607	607	791	19,390	12,900	6,490
1897-98	12,900	1,200	14,100	6,570	7,530	481	544	709	6,821	6,821	....
1898-99	6,821	Transfer at once to Gravel Reservoir. Put all run-off from Arroyo Valle subsequently directly to Gravel Reservoir until Jan. 1, 1906.									
1905-06	Jan. 1 0	11,596	11,596	3,285	8,311	506	253	132	8,179	8,179	.....
1906-07	8,179	28,000	36,179	6,570	29,609	607	557	726	28,883	12,900	15,983
1907-08	12,900	4,800	17,700	6,588	11,112	570	588	766	10,346	10,346	.....
1908-09	10,346	18,000	28,346	6,570	21,776	607	588	766	21,010	12,900	8,110
1909-10	12,900	8,000	20,900	6,570	14,330	607	607	791	13,539	12,900	639
1910-11	12,900	22,000	34,900	6,570	28,330	607	607	791	27,539	12,900	14,639
1911-12	12,900	3,500	16,400	6,588	9,812	542	574	748	9,064	9,064	.....

stored waters would be withdrawn in accordance with the needs of the Gravel Reservoir, drawing the stored water from Arroyo Valle Reservoir as rapidly as possible, for the purpose alike of reducing evaporation from the surface, and making room for any additional flood waters that may come down the creek.

The tabulation of performance has been prepared, having the above conditions in view, leaving the reservoir empty during the period from 1898-99 to 1905-06. To determine the flow secured from Arroyo Valle Creek, the tables of Arroyo Valle Reservoir and the Gravel Reservoir must be considered together.

For the purpose of ascertaining the safe yield of the Arroyo Valle drainage area, as a part of the whole system, a regulated flow has been shown of a steady draft of 18 M. G. D. as the safe yield of the area thus regulated by the reservoir, leaving at the end of the period 9,064 M. G., accumulated and stored, equivalent to one year and four and a half months' supply of 18 M. G. D.

It will be noted that the large amount of surplus, totalling 93,342 M. G. for the period of 23 years is regarded wholly as wasted.

Regulated Flow From Gravel Reservoir in Livermore Valley.

All the other drainage areas not previously considered would be designed to contribute directly to the Gravel Reservoir in the Livermore Valley. These would be the Arroyo Mocho, Arroyo Valle below the reservoir site, the upper and lower Livermore areas, Positas, Tassajero, and Alamo Creeks.

In order to determine the amount of water that can be drawn from the Gravel Reservoir, it is necessary to determine, not only the amount of flow tributary to the area, but also to what extent the flow can enter into the gravel basin.

If all the flow of one year were to enter as one sudden flood, part of the water would not have time to soak in and sink into the gravel, and a great portion would pass off as waste.

In the following will be in detail considered how, and in what amounts the flow enters into the gravel basin.

Construction of Arroyo Valle Reservoir will hold back the floods, until such time as it is convenient to release the flow, and eliminates the flow from that area as contributing to the gravel reservoir during the periods of flood flow. As the distribution has shown, the discharge of the Arroyo Valle Creek averages one-half of the whole contribution to the Livermore Valley.

The flow of the Arroyo Mocho will naturally find its way into the gravels; its discharge has rarely, if ever, contributed to the surface flow of the Creek in the vicinity of Pleasanton. This is also the case with the flow from the Arroyo Valle below the reservoir site, and the upper and lower Livermore areas.

There is, therefore, only to be considered if the discharges coming from the Positas, Tassajero and Alamo Creeks can enter into the gravel beds during their period of flow.

From the Tabulation of Segregated Flow (page 146) it is seen that the combined discharges of the Positas, Tassajero and Alamo Creeks are as follows:

	M. G.
1889-90	19,348
1890-91	4,973
1891-92	....
1892-93	11,742
1893-94	7,581
1894-95	10,306
1895-96	4,472
1896-97	7,866
1897-98	....
1898-99	....
1899-00	....
1900-01	4,230
1901-02	3,406
1902-03	5,895
1903-04	1,191
1904-05	122
1905-06	6,494
1906-07	15,260
1907-08	2,019
1908-09	9,960
1909-10	1,761
1910-11	11,450
1911-12	1,955

In the years of high discharge, 1889-90, 92-93, 94-95, 1906-07 and 1910-11, examination of the total run-off will show that the high discharges continue over a period from 3 to 4 months, with usually one month of extremely high discharge in that period, ranging from two to three times the average discharge of the remaining months of the period of flow.

On the assumption of a distribution of the flow over four months, it will be noted that the maximum discharge, occurring in 1889-90, means an average monthly discharge of 4,837 million gallons, or 161 M. G. D.

To be more exact, the following is the monthly volume of discharge from the Positas, Tassajero and Alamo Creeks, from December, 1889, to June, 1890, inclusive, distributed in the proportion credited to these areas for the season 1889-90.

	Per Month M. G.	Average Per Day M. G.
December	4,073	131.4
January	7,706	248.6
February	3,673	131.2
March	2,088	67.4
April	511	17.0
May	286	9.2
June	110	3.7

Observations of the absorption by the gravel beds are none too numerous, but from what are available a reasonably accurate conclusion can be found of the limitation of such absorption.

Mr. F. H. Tibbetts made two observations in 1906. On the first occasion, Jan. 14th, 1906, of 1136 cubic feet per second passing the Cresta Blanca bridge, only 600 cubic feet per second passed the Pleasanton bridge. The difference absorbed, 536 cubic feet per second, means 346 million gallons per day.

On the second occasion, December 27, 1906, with 270 cubic feet per second observed on the upper section, there were 249 cubic feet per second at the lower, an absorption of 21 cubic feet per second, or 13½ million gallons.

On January 27th, 1912, Messrs. Mulholland and Lippincott observed a complete loss of 45 cubic feet per second—29 M. G. D. in a distance of 3,000 lineal feet of stream channel.

The following are a series of observations of absorption made by Mr. T. W. Espy of the Spring Valley Water Company:

Date, 1912.	Upper Measure. C. F. S.	Upper Measure. M. G. D.	Lower Measure. M. G. D.	Length of Channel. Lin. ft.
March 13	142.5	92	0.0	3,800
" 13	117.6	76	0.0	3,800
" 14	87.8	57	0.0	4,800
" 15	64.0	41	0.0	....
" 16	83.0	54	0.0	....
" 16	72.0	46	0.0	....
" 17	44.0	28	0.0	....
" 18	35.0	23	0.0	2,550

It will be noted that the extreme daily flow from the Positas, Tassajero and Alamo Creeks, 248.6 M. G. per day, January, 1890, does not reach the maximum absorption of 346 M. G. observed in January, 1906. All the other daily flows from these creeks, in that season, are below the absorption observed by Mr. Espy.

It has also to be noted, as will be later evident, that the total volume of flow in the season 1889-90 was otherwise so large that waste was inevitable and has been allowed as such in the table of distribution submitted.

In subsequent years, the tables submitted show an inflow that can be absorbed with readiness, except in such years when the excess is treated as waste in any event.

Further, all these observed absorptions occurred in the natural channel of the creek itself. Development would naturally involve the spreading of the stream discharges over broad areas. There is, therefore, no doubt entertained of the certainty of absorbing all of the waters secured from the three streams remaining as the direct source of supply to the gravel beds during the flood periods, even in seasons of high flow as indicated. In seasons of normal flow, the water would naturally be readily absorbed.

Further, it would be the purpose to keep the water table depressed partly to prevent evaporation loss and partly to provide storage space for flood waters. This would improve absorption conditions.

In this connection there is to be considered the possibility of diverting the Positas, Alamo and Tassajero waters, so that such discharges as do not now enter the gravel beds by reason of the impervious character of the stream beds may be led to suitable locality for absorption.

It is not necessary to enter at this time into any discussion, more or less speculative, of the geological conditions in the vicinity. It is well known that the gravel beds exist, that there is a very large surface area of pervious material, in passing over which water will be absorbed by the gravels. The location of that area is tolerably well defined; it is relatively close to the Positas Creek at one point, and it is not greatly removed from either the Tassajero or Alamo Creeks. From any or all of these creeks, it is a comparatively simple task to create diverting channels, through which their waters can be conveyed to the area known to be absorptive.

The following tables show the estimated performance of the Reservoir in Livermore Valley from 1889 to date.

The inflow is composed of the annual dis-

charge from the following drainage areas—Arroyo Mocho, Arroyo Valle below the reservoir site, the upper and lower Livermore Valleys, Positas, Tassajero and Alamo Creeks, and from 1899 to January 1, 1906, Arroyo Valle above the damsite.

A daily draft of 30 million gallons is assumed, equivalent to an annual draft of 10,950 million gallons.

The flow would be regulated by pumping, or when possible, by drawing from the excess storage in any of the surface reservoirs, particularly Calaveras, Crystal Springs and Arroyo Valle.

The table (pages 164-167) is largely self-explanatory, but some comments in detail may more clearly convey the method of operation.

Commencing with December, 1889, at the beginning of the period of observations, the volumes for the balance of the season are so great that the assumed draft is not sufficiently heavy to take away the flow and the season would end with the reservoir full to the ground surface.

In 1890-91, while the seasonal inflow is less than the seasonal draft, the latter is not sufficient to more than reduce the water table to a height of 4.44 feet above the zero line (which is considered as being 8 feet below the ground surface). The volume embraced in one foot of depth being computed at 850 M. G. on the basis of an area of 24 square miles in the Gravel Reservoir, with 17 per cent porosity.

In the following season, 1891-92, the total deficiency of 10,980 million gallons—the total draft, as there was no inflow in that season, meant a depression of the water table by 12.89 feet, bringing it to a point 8.45 feet below the zero line.

In 1892-93 there is a total inflow of 21,992 million gallons, an excess of 11,042 million gallons over the draft. The water table, at the end of the period, is 5.45 feet above the zero line.

The condition of water table above zero line prevails, in varying depths, until the end of 1895-96. On several occasions during that period, the increase of height above zero line would be above the ground surface and when that occurs the excess is treated as waste, and subsequent reductions of the water table treated as being from the ground surface. In all probability, however, in such periods, the draft from the Gravel Reservoir could be increased and lessened upon the other sources of supply, always with the object of reducing the water table, at least to the zero line, to save evaporation loss, and below that, to provide storage room for the next volume of inflow.

Beginning with 1897-98 a series of years follow one another in which there is an inflow greatly inadequate for the supply of the annual draft commencing with three seasons of no inflow at all.

At that time, at the end of the season 1896-97, there was an accumulation of excess storage from Calaveras Creek of 40,185 M. G., 8,685 M. G. in the Calaveras Reservoir and 31,500 M. G. in the Crystal Springs Reservoir, and this accumulation and the direct flow from the Sunol-Sinbad Creek area would be drawn upon directly when required to meet the deficiency in the Gravel Reservoir as long as it would last, as the tables show, until 1904-05. In other words, the draft upon the surface reservoirs and Gravel Reservoir would be interchangeable, increasing upon the several sources as the demand and the supply would require.

Following upon the season 1904-05, when the excess storage in the surface reservoirs would be exhausted, the deficiency would be met directly by pumping from the Gravel Reservoir, resulting in a maximum depression of the water table, in 1905-06, of 19.61 feet, below the zero line.

As noted on the tables, there were 7,396 M. G. accumulated in the Calaveras Reservoir during the season of 1906-07, which could be drawn upon in place of pumping from the Gravel Reservoir, thereby saving the depression of the water table to the depth equivalent to that volume, or 8.7 feet.

Similar accumulations occur later, in 1908-09, of 8,685 M. G. for Calaveras Reservoir and 2,280 M. G. for Crystal Springs, and again in 1910-11, of 8,685 M. G. for Calaveras Reservoir, and 16 M. G. for Crystal Springs. These accumulations could be drawn upon, in place of continuing draft on Gravel Reservoir. Such a course would lessen surface evaporation in these reservoirs, and increase the height of water table in the Gravel Reservoir. The latter effect might not be desirable; it might be better to have the water table low, as a glance at the monthly positions in those years will show. In Decem-

ber, 1910, the water table is 7.99 feet below the zero line; in January, 1911, it is 0.12 feet above, and in March, 1911, it is 13.72 feet above. In other words, the storage capacity provided by a depth of 8.00 feet was not sufficient to give room to the large inflow in these months, without rising above the zero line.

The illustration fully indicates the advisability of maintaining a steady and relatively high draft upon the Gravel Reservoir and affords proof of the value of the interchanegability of the various parts of the system.

With these notes the tables submitted on the following pages set out clearly that a draft of 30 M. G. D. can be safely maintained through the entire period, with an extreme depression of 19.61 feet, in one month, December, 1905.

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Assume water plane at 0.00, 8 feet below ground surface at start. Consider flow from Sunol-Sinbad Creek area.

1889-90.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
Dec......	7,542	600(a)	+ 6,942	+ 8.16	+ 8.16*
Jan......	14,263	...(b)	+14,263	+16.78	+24.94*
Feb......	6,801	...(c)	+ 6,801	+ 8.00	+32.94*
March...	3,870	930(d)	+ 2,940	+ 3.46	+36.40*
April....	953	900(e)	+ 53	+ .06	+36.46*
May.....	537	930	— 393	— .46	+ 7.54†
June.....	211	900	— 689	— .81	+ 6.73
	34,177				

1890-91.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					+ 6.73
July.....	155	930	— 775	— .91	+ 5.82
Aug......	132	930	— 798	— .94	+ 4.88
Sept.....	118	900	— 782	— .92	+ 3.96
Oct......	124	930	— 806	— .95	+ 3.01
Nov.....	124	900	— 776	— .91	+ 2.10
Dec......	253	930	— 677	— .80	+ 1.30
Jan......	273	930	— 657	— .77	+ .53
Feb......	3,159	840	+ 2,319	+ 2.73	+ 3.26
March...	3,553	930	+ 2,623	+ 3.09	+ 6.35
April....	643	900	— 257	— .30	+ 6.05
May.....	288	930	— 642	— .75	+ 5.30
June.....	172	900	— 728	— .86	+ 4.44

*Above ground surface (waste).
†Starting from ground surface.
(a) 330 M. G. for December from Sunol-Sinbad Creek area.
(b) 3,100 M. G. for January from Sunol-Sinbad Creek area (full capacity of conduit).
(c) 2,800 M. G. for February from Sunol-Sinbad Creek area (full capacity of conduit).
(d) 1,720 M. G. for March from Sunol-Sinbad Creek area, leaving 1,380 M. G. capacity to fill draught.
(e) 540 M. G. for April from Sunol-Sinbad Creek area, leaving 2,460 M. G. capacity to fill draught.

1891-92.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					+ 4.44
July.....	0.0	930	— 930	— 1.09	+ 3.35
Aug.....	0.0	930	— 930	— 1.09	+ 2.26
Sept.....	0.0	900	— 900	— 1.06	+ 1.20
Oct......	0.0	930	— 930	— 1.09	+ 0.11
Nov.....	0.0	900	— 900	— 1.06	— 0.95
Dec......	0.0	930	— 930	— 1.09	— 2.04
Jan......	0.0	930	— 930	— 1.09	— 3.13
Feb......	0.0	870	— 870	— 1.02	— 4.15
March...	0.0	930	— 930	— 1.09	— 5.24
April....	0.0	900	— 900	— 1.06	— 6.30
May.....	0.0	930	— 930	— 1.09	— 7.39
June.....	0.0	900	— 900	— 1.06	— 8.45

1892-93.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					— 8.45
July.....	60	930	— 870	— 1.02	— 9.47
Aug.....	33	930	— 897	— 1.05	—10.52
Sept.....	22	900	— 878	— 1.03	—11.55
Oct......	22	930	— 908	— 1.07	—12.62
Nov.....	3,015	900	+ 2,115	+ 2.49	—10.13
Dec......	8,639	930	+ 7,709	+ 9.07	— 1.06
Jan......	2,671	930	+ 1,741	+ 2.05	+ 0.99
Feb......	4,752	840	+ 3,912	+ 4.60	+ 5.59
March...	1,172	163(a)	+ 1,009	+ 1.19	+ 6.78
April....	1,074	900	+ 174	+ 0.20	+ 6.98
May.....	437	930	— 493	— 0.58	+ 6.40
June.....	95	900	— 805	— 0.95	+ 5.45

1893-94.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					+ 5.45
July.....	90	930	— 840	— 0.99	+ 4.46
Aug.....	67	930	— 863	— 1.01	+ 3.45
Sept.....	45	900	— 855	— 1.00	+ 2.45
Oct......	29	930	— 901	— 1.06	+ 1.39
Nov.....	47	900	— 853	— 1.00	+ 0.39
Dec......	94	930	— 836	— 0.98	— 0.59
Jan......	3,673	...(c)	+ 3,673	+ 4.32	+ 3.73
Feb......	8,355	...(b)	+ 8,355	+ 9.83	+13.56†
March...	860	930	— 70	— .08	+ 7.92
April....	206	900	— 694	— .82	+ 7.10
May.....	124	930	— 806	— .95	+ 6.15
June.....	81	900	— 819	— .96	+ 5.19
	13,671				

1894-95.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					+ 5.19
July.....	61	930	— 869	— 1.02	+ 4.17
Aug.....	38	930	— 892	— 1.05	+ 3.12
Sept.....	34	900	— 866	— 1.02	+ 2.10
Oct......	50	930	— 880	— 1.04	+ 1.06
Nov.....	24	900	— 876	— 1.03	+ 0.03
Dec......	3,871	930	+ 2,941	+ 3.46	+ 3.43
Jan......	10,655	...(d)	+10,655	+12.54	+15.97†
Feb......	2,768	...(e)	+ 2,768	+ 3.25	+19.22†
March...	669	930	— 261	— 0.31	+ 7.69
April....	453	900	— 447	— 0.53	+ 7.16
May.....	342	930	— 558	— 0.69	+ 6.47
June.....	107	900	— 793	— 0.93	+ 5.54

†Above ground surface.
(a) 2,937 M. G. from Sunol-Sinbad Creek area, leaving 163 M. G. to capacity of conduit.
(b) 2,800 M. G. from Sunol-Sinbad Creek area—full capacity of conduit.
(c) 3,100 M. G. from Sunol-Sinbad Creek area—full capacity of conduit.
(d) 3,100 M. G. from Sunol-Sinbad Creek area—full capacity of conduit.
(e) 2,800 M. G. from Sunol-Sinbad Creek area—full capacity of conduit.

1895-96.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					+ 5.54
July.....	60	930	— 870	— 1.02	+ 4.52
Aug.....	58	930	— 872	— 1.02	+ 3.50
Sept.....	57	900	— 843	— 0.99	+ 2.51
Oct......	77	930	— 853	— 1.00	+ 1.51
Nov.....	78	900	— 822	— 0.97	+ 0.54
Dec......	89	930	— 841	— 0.99	— 0.45
Jan......	4,551	400(a)	+ 4,151	+ 4.88	+ 4.43
Feb......	451	870	— 419	— 0.49	+ 3.94
March...	480	930	— 450	— 0.53	+ 3.41
April....	2,293	900	+ 1,393	+ 1.64	+ 5.05
May.....	557	930	— 373	— 0.44	+ 4.61
June.....	136	900	— 764	— 0.90	+ 3.71

1896-97.

					+ 3.71
July.....	65	930	— 865	— 1.02	+ 2.69
Aug.....	50	930	— 880	— 1.04	+ 1.65
Sept.....	49	900	— 851	— 1.00	+ 0.65
Oct......	56	930	— 874	— 1.03	— 0.38
Nov.....	326	900	— 574	— 0.68	— 1.06
Dec......	515	930	— 415	— 0.49	— 1.55
Jan......	530	930	— 400	— 0.47	— 2.02
Feb......	5,516	840	+ 4,676	+ 5.50	+ 3.48
March...	5,768	741(b)	+ 5,027	+ 5.91	+ 9.39*
April....	935	900	+ 35	+ 0.04	+ 9.43*
May.....	244	930	— 686	— 0.81	+ 7.19
June.....	82	900	— 818	— 0.96	+ 6.23

1897-98.

					+ 6.23
July.....	0.0	930	— 930	— 1.09	+ 5.14
Aug.....	0.0	930	— 930	— 1.09	+ 4.05
Sept.....	0.0	900	— 900	— 1.06	+ 2.99
Oct......	0.0	930	— 930	— 1.09	+ 1.90
Nov.....	0.0	900	— 900	— 1.06	+ 0.84
Dec......	0.0	930	— 930	— 1.09	— 0.25
Jan......	0.0	930	— 930	— 1.09	— 1.34
Feb......	0.0	840	— 840	— 0.99	— 2.33
March...	0.0	930	— 930	— 1.09	— 3.42
April....	0.0	900	— 900	— 1.06	— 4.48
May.....	0.0	930	— 930	— 1.09	— 5.57
June.....	0.0	900	— 900	— 1.06	— 6.63

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Withdraw all stored water in Arroyo Valle Reservoir at beginning of season=6,821 M. G.= 8.02 feet. Put all Arroyo Valle water directly into gravel reservoir. Draw Arroyo Valle daily draft, 18 M. G. D., directly from reservoir. Draw equivalent of 30 M. G. D. for gravel reservoir from Crystal Springs Reservoir (holding 31,500 M. G. at start).

—6.63 at beginning.

Add Arroyo Valle= 8.02 at beginning.

+1.39 at beginning.

(a) 2,700 M. G. from Sunol-Sinbad area, leaving 400 M. G. for gravel reservoir.

*Above ground surface.

(b) 2,359 M. G. from Sunol-Sinbad Creek area, leaving 741 M. G. to capacity of conduit.

1898-99.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					+ 1.39
July.....	29	558	— 529	— .62	+ 0.77
Aug.....	22	558	— 536	— .63	+ 0.14
Sept.....	23	540	— 517	— .61	— 0.47
Oct......	37	558	— 521	— .61	— 1.08
Nov.....	37	540	— 503	— .59	— 1.67
Dec......	38	558	— 520	— .61	— 2.28
Jan......	113	558	— 445	— .52	— 2.80
Feb......	43	504	— 461	— .54	— 3.34
March...	4,363	...(a)	+ 4,363	+ 5.13	+ 1.79
April....	231	540	— 309	— .36	+ 1.43
May.....	80	558	— 478	— .56	+ 0.87
June.....	84	540	— 456	— .54	+ 0.33
	5,100				

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Put all Arroyo Valle water directly into gravel reservoir. Draw Arroyo Valle daily draft=18 M. G. D. directly from gravel reservoir. Draw equivalent of 30 M. G. D. for gravel reservoir from Crystal Springs Reservoir=(10,950 M. G. during year.)

1899-1900.

					+ 0.33
July.....	53	558	— 505	— 0.59	— 0.26
Aug.....	50	558	— 508	— 0.60	— 0.86
Sept.....	47	540	— 493	— 0.58	— 1.44
Oct......	50	558	— 508	— 0.60	— 2.04
Nov.....	136	540	— 404	— 0.48	— 2.52
Dec......	447	558	— 111	— 0.13	— 2.65
Jan......	2,547	558	+ 1,989	+ 2.34	— 0.31
Feb......	168	504	— 336	— 0.40	— 0.71
March...	533	558	— 25	— 0.03	— 0.74
April....	187	540	— 353	— 0.41	— 1.15
May.....	121	558	— 437	— 0.51	— 1.66
June....	61	540	— 479	— 0.56	— 2.22

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Put all run-off from Arroyo Valle and other tributaries directly into Gravel Reservoir. Draw all of Arroyo Valle—18 M. G. D. from it. Draw all of Gravel Reservoir—30 M. G. D. from it.

1900-01.

					— 2.22
July.....	95	1,488	— 1,393	— 1.64	— 3.86
Aug.....	93	1,488	— 1,395	— 1.64	— 5.50
Sept.....	87	1,440	— 1,353	— 1.59	— 7.09
Oct......	169	1,488	— 1,319	— 1.55	— 8.64
Nov.....	3,282	1,440	+ 1,842	+ 2.17	— 6.47
Dec......	484	1,488	— 1,004	— 1.18	— 7.65
Jan......	2,558	1,488	+ 1,070	+ 1.26	— 6.39
Feb......	7,130	...(b)	+ 7,130	+ 8.39	+ 2.00
March...	1,370	1,488	— 118	— 0.14	+ 1.86
April....	585	1,440	— 855	— 1.01	+ .85
May.....	547	1,488	— 941	— 1.11	— .26
June.....	280	1,440	— 1,160	— 1.36	— 1.62

(a) 3,100 M. G. from Sunol-Sinbad Creek area—full capacity of conduit—in March.

(b) 2,800 M. G. from Sunol-Sinbad Creek area—full capacity of conduit.

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Put all run-off from Arroyo Valle and tributaries into Gravel Reservoir. Draw all of 30 M. G. D. from Gravel Reservoir. Draw all of 18 M. G. D. (Arroyo Valle) from Gravel Reservoir.

1901-02.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					— 1.62
July.....	202	1,488	— 1,286	— 1.51	— 3.13
Aug.....	149	1,488	— 1,339	— 1.58	— 4.71
Sept.....	119	1,440	— 1,321	— 1.55	— 6.26
Oct......	119	1,488	— 1,369	— 1.61	— 7.87
Nov.....	125	1,440	— 1,315	— 1.55	— 9.42
Dec......	280	1,488	— 1,208	— 1.42	—10.84
Jan......	135	1,488	— 1,353	— 1.59	—12.43
Feb......	3,728	763(a)	+ 2,965	+ 3.49	— 8.94
March...	5,521	1,488	+ 4,033	+ 4.74	— 4.20
April....	1,030	1,440	— 410	— 0.48	— 4.68
May.....	470	1,488	— 1,018	— 1.19	— 5.87
June.....	246	1,440	— 1,194	— 1.40	— 7.27

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Put all run-off from Arroyo Valle and tributaries into Gravel Reservoir. Draw all of 30 M. G. D. from Gravel Reservoir. Draw all of 18 M. G. D. (Arroyo Valle) from Gravel Reservoir.

1902-03.

					— 7.27
July.....	229	1,488	— 1,259	— 1.48	— 8.75
Aug.....	191	1,488	— 1,297	— 1.53	—10.28
Sept.....	144	1,440	— 1,296	— 1.52	—11.80
Oct......	159	1,488	— 1,329	— 1.56	—13.36
Nov.....	209	1,440	— 1,231	— 1.45	—14.81
Dec......	201	1,488	— 1,287	— 1.51	—16.32
Jan......	3,598	1,488	+ 2,110	+ 2.48	—13.84
Feb......	2,933	1,344	+ 1,589	+ 1.87	—11.97
March...	6,037	569(b)	+ 5,468	+ 6.44	— 0.41
April....	5,790	1,440	+ 4,350	+ 5.12	— 0.41
May.....	688	1,488	— 800	— .94	— 1.35
June.....	319	1,440	— 1,121	— 1.32	— 2.67

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Put all run-off from Arroyo Valle and other tributaries into Gravel Reservoir. Draw equivalent of 30 M. G. D. from Crystal Springs Reservoir or Calaveras Reservoir surplus. Remaining in Crystal Springs at beginning of season 9,600 M. G.—and 8,685 M. G. in Calaveras Reservoir surplus. Total draft for season—10,980 M. G. would leave—7,305 in Calaveras.

1903-04.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					— 2.67
July.....	109	558	— 449	— 0.53	— 3.20
Aug.....	82	558	— 476	— 0.56	— 3.76
Sept.....	86	540	— 454	— 0.53	— 4.29
Oct......	62	558	— 496	— 0.58	— 4.87
Nov.....	153	540	— 387	— 0.45	— 5.32
Dec......	98	558	— 460	— 0.54	— 5.86
Jan......	103	558	— 455	— 0.54	— 6.40
Feb......	1,625	...(a)	+ 1,625	+ 1.91	— 4.49
March...	3,088	558(b)	+ 2,530	+ 2.98	— 1.51
April....	1,072	540	+ 532	+ 0.63	— 0.88
May.....	427	558	— 131	— 0.15	— 1.03
June.....	135	540	— 405	— 0.48	— 1.51

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Put all run-off from Arroyo Valle and other tributaries in Gravel Reservoir. Draw 18 M. G. D. (Arroyo Valle) direct from Gravel Reservoir. Draw 30 M. G. D. from Calaveras Reservoir surplus up to 7,005 M. G. to February 18, 1905, leaving 300 M. G. in Calaveras surplus.

1904-05.

					— 1.51
July.....	90	558	— 468	— 0.55	— 2.06
Aug.....	112	558	— 446	— 0.52	— 2.58
Sept.....	60	540	— 480	— 0.56	— 3.14
Oct......	63	558	— 495	— 0.58	— 3.72
Nov.....	65	540	— 475	— 0.56	— 4.28
Dec......	100	558	— 458	— 0.54	— 4.82
Jan......	235	558	— 323	— 0.38	— 5.20
Feb......	600	804	— 204	— 0.24	— 5.44
March...	1,058	1,488	— 430	— 0.51	— 5.95
April....	358	1,440	— 1,082	— 1.27	— 7.22
May.....	308	1,488	— 1,180	— 1.39	— 8.61
June.....	108	1,440	— 1,332	— 1.57	—10.18

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

Put all run-off from Arroyo Valle and other tributaries into Gravel Reservoir until January 1, 1906. After that hold Arroyo Valle run-off in Arroyo Valle Reservoir. Draw 30 M. G. D. continuously from Gravel Reservoir. Draw 18 M. G. D. from Gravel Reservoir until January 1, 1906. After that from Arroyo Valle Reservoir.

(a) 2,037 M. G. from Sunol-Sinbad Creek area, leaving 763 M. G. for full capacity of conduit.
(b) 2,531 M. G. from Sunol-Sinbad Creek area in March, leaving 569 M. G. for capacity of conduit.

(a) 2,800 M. G. from Sunol-Sinbad Creek area—full capacity of conduit.
(b) 2,470 M. G. from Sunol-Sinbad Creek area, leaving 630 M. G. capacity in conduit.

1905-06.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					—10.18
July.....	189	1,488	— 1,299	— 1.53	—11.71
Aug.....	170	1,488	— 1,318	— 1.55	—13.26
Sept.....	121	1,440	— 1,319	— 1.55	—14.81
Oct......	107	1,488	— 1,381	— 1.62	—16.43
Nov.....	105	1,440	— 1,335	— 1.57	—18.00
Dec......	118	1,488	— 1,370	— 1.61	—19.61
Jan......	3,070	...(a)	+ 3,070	+ 3.61	—16.00
Feb......	1,400	840	+ 560	+ 0.66	—15.34
March...	4,566	...(b)	+ 4,566	+ 5.37	— 9.97
April....	1,646	900	+ 746	+ 0.88	— 9.09
May.....	461	930	— 469	— 0.55	— 9.64
June.....	274	900	— 626	— 0.74	—10.38

GRAVEL RESERVOIR.

ESTIMATED PERFORMANCE UNDER CONTINUED DRAFT OF 30 M. G. D.

1906-07.

					—10.38
July.....	167	930	— 763	— 0.90	—11.28
Aug.....	127	930	— 803	— 0.94	—12.22
Sept.....	122	900	— 778	— 0.91	—13.13
Oct......	110	930	— 820	— 0.95	—14.08
Nov.....	105	900	— 795	— 0.93	—15.01
Dec......	1,675	930	+ 745	+ 0.88	—14.13
Jan......	5,511	930	+ 4,581	+ 5.39	— 8.74
Feb......	2,272	840	+ 1,432	+ 1.68	— 7.06
March...	14,463	930(c)	+13,533	+15.92	+ 8.86*
April....	1,911	900	+ 1,011	+ 1.19	+10.05*
May.....	642	930	— 288	— 0.34	+ 7.66
June.....	345	900	— 555	— 0.65	+ 7.01

1907-08.

					+ 7.01
July ...	210	930	— 720	— 0.85	+ 6.16
Aug. ...	150	930	— 780	— 0.92	+ 5.24
Sept. ...	105	900	— 795	— 0.94	+ 4.30
Oct.	103	930	— 827	— 0.97	+ 3.33
Nov. ...	130	900	— 770	— 0.91	+ 2.42
Dec. ...	362	930	— 568	— 0.67	+ 1.75
Jan.	886	720(d)	+ 166	+ 0.19	+ 1.94
Feb. ...	797	870	— 73	— 0.09	+ 1.85
March ..	701	930	— 229	— 0.27	+ 1.58
April ..	202	900	— 698	— 0.82	+ 0.76
May ...	157	930	— 773	— 0.91	— 0.15
June ...	97	900	— 803	— 0.94	— 1.09

1908-09.

					— 1.09
July ...	110	930	— 820	— 0.96	— 2.05
Aug. ...	85	930	— 845	— 0.99	— 3.04
Sept. ...	73	900	— 827	— 0.97	— 4.01
Oct.	65	930	— 865	— 1.02	— 5.03
Nov. ...	63	900	— 837	— 0.98	— 6.01
Dec. ...	74	930	— 856	— 1.01	— 7.02
Jan. ...	7,811	....(e)	+ 7,811	+ 9.19	+ 2.17
Feb. ...	6,961	140(f)	+ 6,821	+ 8.02	+10.19*
March ..	2,017	930	+ 1,087	+ 1.28	+11.47*
April ...	416	900	— 484	— 0.57	+ 7.43
May ...	186	930	— 744	— 0.87	+ 6.56
June ...	139	900	— 761	— 0.89	+ 5.67

(a) 3,100 M. G. from Sunol-Sinbad Creek area in January—full capacity of conduit.
(b) 3,100 M. G. from Sunol-Sinbad Creek area in March—full capacity of conduit.
*Above ground surface.
(c) 3,100 M. G. from Sunol-Sinbad Creek area—full capacity of conduit—if needed.
(d) 2,380 M. G. from Sunol-Sinbad Creek area, leaving 720 M. G. for full capacity of conduit. Surplus at Calaveras Reservoir this year, 5,273 M. G.
(e) 3,100 M. G. from Sunol-Sinbad Creek area—full capacity of conduit.
(f) 2,660 M. G. from Sunol-Sinbad Creek area, leaving 140 M. G. to full capacity of conduit.

1909-10.

	Inflow from all sources. M. G.	Monthly draft. M. G.	Gain or loss. M. G.	Gain or loss. Feet.	Height of water table. Feet.
					+ 5.67
July ...	69	930	— 861	— 1.01	+ 4.66
Aug. ...	64	930	— 866	— 1.02	+ 3.64
Sept. ..	63	900	— 837	— 0.98	+ 2.66
Oct.	73	930	— 857	— 1.01	+ 1.65
Nov. ...	65	900	— 835	— 0.98	+ 0.67
Dec.	460	930	— 470	— 0.55	+ 0.12
Jan. ..	1,468	930	+ 538	+ 0.63	+ 0.75
Feb. ...	607	840	— 237	— 0.28	+ 0.47
March ..	757	930	— 173	— 0.20	+ 0.27
April ...	335	900	— 565	— 0.66	— 0.39
May	153	930	— 777	— 0.91	— 1.20
June ...	86	900	— 814	— 0.96	— 2.16

1910-11.

					— 2.16
July ...	125	930	— 805	— 0.95	— 3.11
Aug. ...	120	930	— 810	— 0.95	— 4.06
Sept. ...	95	900	— 805	— 0.95	— 5.01
Oct. ...	50	930	— 880	— 1.03	— 6.04
Nov. ...	75	900	— 825	— 0.97	— 7.01
Dec.	100	930	— 830	— 0.98	— 7.99
Jan.	6,890	...(a)	+ 6,890	+ 8.11	+ 0.12
Feb. ...	2,820	840	+ 1,980	+ 2.33	+ 2.45
March	9,785	207(b)	+ 9,578	+11.27	+13.72†
April ...	530	900	— 370	— 0.44	+ 7.56
May	260	930	— 670	— 0.79	+ 6.77
June ...	150	900	— 750	— 0.88	+ 5.89

1911-12.

					+ 5.89
July ...	181	930	— 749	— 0.88	+ 5.01
Aug. ...	195	930	— 735	— 0.86	+ 4.15
Sept. ...	160	900	— 740	— 0.87	+ 3.28
Oct. ..	175	930	— 755	— 0.89	+ 2.39
Nov. ...	180	900	— 720	— 0.85	+ 1.54
Dec.	193	930	— 737	— 0.86	+ 0.68
Jan.	423	930	— 507	— 0.60	+ 0.08
Feb.	325	870	— 545	— 0.64	— 0.56
March ..	968	930	+ 38	+ 0.04	— 0.52
April ...	335	900	— 565	— 0.66	— 1.18
May	205	930	— 725	— 0.85	— 2.03
June ...	160	900	— 740	— 0.87	— 2.90

Water Secured From Reduction of Evaporation Loss.

Upon this feature, reference is made to the accompanying report on Evaporation from Wet Lands in Livermore Valley (page 482), in which the results observed by the Los Angeles Aqueduct Commission are considered in relation to the Livermore Valley, following a thorough field investigation of the existing conditions.

It is there shown that the average annual loss by evaporation and transpiration from the wet lands in the Livermore Valley, prior to effective drainage, amounted to 21 M. G. D. and had been reduced, in the dry season of 1912, to 10 M. G. D. Of the total of 21 M. G. D., considering that some portion of the total area may not drain

†Above ground surface.
(a) 3,100 M. G. from Sunol-Sinbad Creek area—full capacity of conduit in January.
(b) 2,893 M. G. from Sunol-Sinbad Creek area in March, leaving 207 for capacity of conduit.

readily and that a complete saving could not be economically effected, 75 per cent is assumed or a total of 15.7 M. G. D.

It is intended, in the development of the Gravel Reservoir, to maintain the water table at 8 feet below the ground surface, and as the tables of draft submitted show that it would not always be possible to maintain the water table below that level, some further reduction of the gain should be made. Assuming this amount at 25 per cent, there would be a gain of 11.775 M. G. D. from this source, or say 12 M. G. D.

Local Consumption of Water in Livermore Valley.

The information regarding the present consumption of water in the Livermore Valley, consisting, outside of the domestic supply of the towns of Pleasanton and Livermore, of household supply on the various farms, for industrial uses, road sprinkling, etc., is not very extensive. The town supplies are given as approximately 800,000 gallons per day, and the other uses about 700,000 gallons per day, or a total of 1,500,000 gallons per day.

This appears to be a high estimate, and considering future developments, it is believed that an allowance of 2 M. G. D. will fully cover the consumption of the Livermore Valley for some time to come.

SUMMARY OF REGULATED FLOW FROM ALAMEDA SYSTEM.

Calaveras Reservoir.

The tabulation has shown that there is a safe daily yield of 57 M. G. D. In addition to that, there has been a surplus accumulated during the period of 23 years, stored in either Calaveras or Crystal Springs Reservoirs, and used as supplemental when and where required, a total of 123,249 M. G., of which amount 39,885 M. G. has been utilized to equalize the Gravel Reservoir, leaving 83,364 million gallons available. This is equivalent to an annual yield of 3,625 M. G., or a daily yield of 9.93 M. G. D.

San Antonio Reservoir.

The tabulation has shown this reservoir to be able to supply a safe yield of 8.5 M. G. D. supplemented by direct flow from Sunol-Sinbad Creek area.

Sunol-Sinbad Creek Area.

For this area has been shown a controlled flow aggregating 84,777 M. G. for 23 years or

TABULATION SHOWING DIRECT FLOW FROM SUNOL AREA USED TO EQUALIZE FLOW FROM OTHER RESERVOIRS.

Gravel Reservoir.		M. G.	Arroyo Valle Reservoir.		M. G.	San Antonio Reservoir.		M. G.
1892-93	March	767						
1893-94	Jan.	930						
	Feb.	840						
1894-95	Jan.	930						
	Feb.	840						
1895-96	Jan.	530						
1896-97	March	189	1898-99	March	558	1898-99	March	263.5
1900-01	Feb.	840	1900-01	Feb.	504		Feb.	238.0
1901-02	Feb.	77		Feb.	504		Feb.	238.0
1902-03	March	361		March	558		March	263.5
			1903-04	Feb.	522		Feb.	246.5
							March	191.5
1905-06	Jan.	930		Jan.	558		Jan.	263.5
	March	930		March	558		March	263.5
1907-08	Jan.	210					Jan.	263.5
1908-09	Jan.	930					Jan.	263.5
1908-09	Feb.	700					Feb.	238.0
1910-11	Jan.	930					Jan.	263.5
	March	723					March	263.5
Total		11,657			3,762			3,260.0

Grand Total.	M. G.
Gravel Reservoir	11,657
Arroyo Valle Reservoir	3,762
San Antonio Reservoir	3,260
	18,679

10.10 M. G. D. From that has to be deducted the direct draft used to equalize other parts of the system, in this instance the Gravel Reservoir, Arroyo Valle Reservoir and San Antonio Reservoir.

The foregoing tabulated statement shows the amounts used for these various reservoirs, with the dates, and these amounts have been deducted from the yield of the Sunol-Sinbad Creek area.

For the whole period of 23 years the flow used to equalize the reservoirs amounts to an annual average of 812.1 M. G., giving a daily average of 2.2 M. G. D., which, deducted from the total average of 10.10 M. G. D., leaves 7.9 M. G. D. as the safe daily yield from the Sunol-Sinbad Creek area.

Arroyo Valle Reservoir.

Arroyo Valle Reservoir has been shown to be capable of delivering a safe daily yield of 18 M. G. D.

Gravel Reservoir.

The Gravel Reservoir has been shown to be capable of supplying 30 M. G. D.

Evaporation.

Lowering of the water table will reduce evaporation losses from the wet lands. Corresponding increase of flow is estimated as 12 M. G. D.

Local Consumption.

To provide for local consumption has been set aside a flow of 2. M. G. D.

Safe Daily Yield of Alameda Creek System 140 M. G. D.

In final review the items from the various sources may be once more briefly set out and summarized. The following is submitted as a conservative statement of the safe daily yield from the Alameda Creek System:

	M. G. D.
Calaveras Reservoir, direct....... ..	57.00
Calaveras Reservoir, storage of surplus	9.93
San Antonio Reservoir................	8.50
Sunol-Sinbad Creek area..............	7.90
Arroyo Valle Reservoir...............	18.00
Livermore Gravel Reservoir..........	30.00
Evaporation in Livermore Valley......	12.00
	143.33
Less for local consumption..........	2.00
	141.33

Say 140 million gallons per day as the safe yield of the Alameda Creek System, over a period of years, full development being made of all reservoir systems and the feature of the interchangeability of the system as a whole being fully taken advantage of.

It remains to point out that at the end of the period of twenty-three years considered there was in reserve storage the following amounts:

	M. G.
Calaveras Reservoir, direct..........	26,866
Calaveras Reservoir, surplus stored..	10,981
San Antonio Reservoir	1,843
Arroyo Valle Reservoir..............	9,064
	48,754

which, on the basis of 128 M. G. D. draft, leaving out of consideration the 12 M. G. D. secured from evaporation, would be sufficient to care for the whole supply for more than one year, without increment from any source, and that does not include any amount obtained from the Gravel Reservoir, the water table of which, at the end of the period, was 2.9 feet below the zero line.

PENINSULA SYSTEM.

The Peninsula System comprises three reservoirs, Crystal Springs, San Andreas, and Pilarcitos with appurtenant works.

In order to determine the safe, dependable daily yield from the system, consideration has been taken of the storage accumulated in them throughout their history, the draft made upon them, and the waste, or surplus, that may have passed over their spillways.

As commented on in detail, the three reservoirs are considered as operated in one system; draft and storage being increased or decreased for each of them as conditions and good management dictate, with the purpose of securing full conservation of the run-off from the tributary watershed. The system lends itself particularly to interchangeable operation of the supply, and, unless recognition is taken of that valuable feature, full advantage of the available stream flow will not be secured, and the reasonable capacity of the system, as a whole, will not be realized.

In the following analysis, each reservoir has been considered separately, and due notations have been made of occasional temporary changes of continuous draft, due to increased

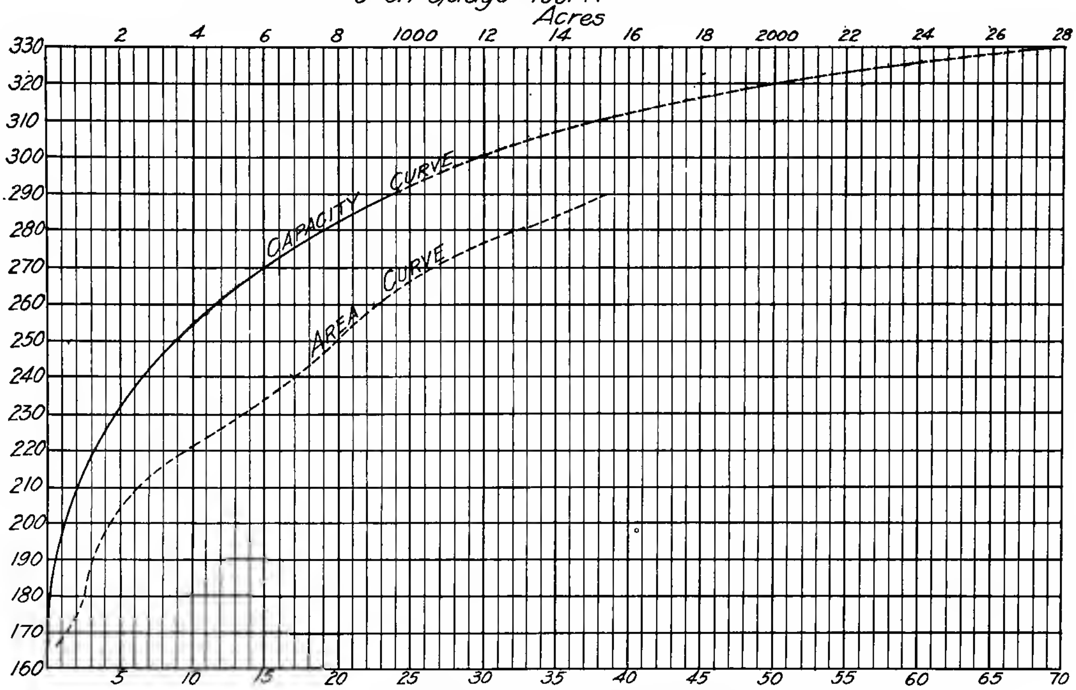
CRYSTAL SPRINGS RESERVOIR

Capacity and Area.

Contour Elevation	Area in Acres	Capacity in M.G.
166	36.8	0.00
180	93.2	296.36
200	177.4	1176.62
220	382.6	2998.22
240	678.4	6454.22
260	911.6	11631.28
280	1326.4	18913.63
290	1533.6	23573.01
310		38000.00
330		69000.00

	Crest	Max. Ht. of Water	Capacity	Outlet
Present	288.85 Ft.	288 Ft.	23,500 M.G.	177.87 Ft.
Ultimate	328.00 Ft.	323 Ft.	55,000 M.G.	177.87 Ft.

0 on Gauge -166 Ft.



Note:- Capacity Curve above 290' Contour approximate only.

Calculations from R-27a.

Crystal Springs Datum.

From Records of S.V.W. Co.

Drawn by A. J. Krutmeyer S.V.W.Co.

Compared & Checked by H. [signature] S.V.W.Co.

SPRING VALLEY WATER CO.
San Francisco
July - 1912

Anderson C-4

SHOWING THAT STORAGE OF 63,000 M. G. MAY READILY BE OBTAINED ONLY 16 MILES FROM SAN FRANCISCO.

or decreased demands on the parts of the system.

Crystal Springs Reservoir Will Safely Yield 9.8 M. G. D.

The water withdrawn from Crystal Springs and conveyed directly to the City, has been delivered into University Mound Regulating Reservoir, in conjunction with the supply from the Alameda Creek. The total inflow at University Mound is measured by a weir, and the records of inflow have been thoroughly checked. By deducting the quantity of water from Alameda Creek as shown by the record of the Belmont pumps, established in connection with the flow of the Alameda Creek, the inflow from Crystal Springs is determined.

Occasionally, additional draft has been made upon Crystal Springs by the Millbrae pumps, and by the Crystal Springs pumps.

All the records of draft made by any of these means since 1889 have been examined, as well as the records of the storage in the reservoir. The following tabulation, showing the total available water supply from Crystal Springs Reservoir, contains complete and accurate record of the flow.

The table commences with the year 1890. Records for a previous period exist, but those of 1889 were destroyed in the fire of 1906. Examination of the records prior to 1889 indicates, however, that the continuous draft shown by the tabulation could have been maintained in the preceding years.

The tabulation commencing 1890 sets out the accumulated storage at the beginning and at the end of each year. The difference, whether gain or loss, is added to the draft recorded for that year, the result giving the total net inflow. The records of depth of water stored record actual conditions, taking into account the loss from evaporation and all other causes. The total net inflow, less the amount of continuous draft, is added to the quantity stored at the beginning of the year. The result shows the quantity in storage at the end of the year. The condition of the reservoir is thus shown throughout the period of the 21.5 years considered.

The tabulation shows that a continuous draft of 9.8 million gallons per day can be maintained. The lowest storage at the end of any year, is in 1908, immediately preceding the period of run-off in the streams, being 1056.1 million gallons.

TABULATION OF PERFORMANCE—CRYSTAL SPRINGS RESERVOIR.

	SPRING VALLEY WATER COMPANY RECORDS.						ESTIMATED PERFORMANCE.		
	In Storage First of Year. M. G.	In Storage End of Year. M. G.	Gain. M. G.	M. G. Draft. Total	M. G. Waste.	M. G. Inflow. Total	Estimated M. G. Draft.	Remainder. M. G.	In Storage End of Year. M. G.
1890	7,196	8,730	1,534	1,660	6,737	+9,931	3,577	+6,354.0	13,550.0
1891	8,730	10,788	2,058	1,180.6	....	+3,238.6	3,577	— 339.6	13,210.4
1892	10,788	11,400	612	1,612.8	....	+2,224.8	3,586.8	—1,362.0	11,848.4
1893	11,400	14,439	3,039	2,050.6	....	+5,089.6	3,577	+1,512.6	13,361.0
1894	14,439	18,380	3,941	2,401.3	....	+6,342.3	3,577	+2,765.3	16,126.3
1895	18,380	16,127	—2,253	2,619	4,674	+5,040.0	3,577	+1,463.0	17,589.3
1896	16,127	16,580	+ 453	2,429.6	....	+2,882.6	3,586.8	— 704.2	16,885.1
1897	16,580	14,650	—1,930	3,719.1	1,770	+3,559.1	3,577	— 17.9	16,867.2
1898	14,650	9,200	—5,450	3,778.2	....	—1,671.8	3,577	—5,148.8	11,718.4
1899	9,200	7,200	—2,000	4,327.9	....	+2,327.9	3,577	—1,249.1	10,469.3
1900	7,200	6,050	—1,150	2,446.8	....	+1,296.8	3,577	—2,280.2	8,189.1
1901	6,050	5,230	— 820	1,538.9	....	+ 718.9	3,577	—2,858.1	5,331.0
1902	5,230	4,828	— 402	1,478.3	....	+1,076.3	3,577	—2,500.7	2,830.3
1903	4,828	6,936	+2,108	658.0	....	+2,766.0	3,577	— 811.0	2,019.3
1904	6,936	10,846	+3,910	1,133.8	....	+5,043.8	3,586.8	+1,457.0	3,476.3
1905	10,846	10,227	— 619	2,433.4	....	+1,814.4	3,577	—1,762.6	1,713.7
1906	10,227	12,560	+2,333	1,093.2	....	+3,426.2	3,577	— 150.8	1,562.9
1907	12,560	17,392	+4,832	1,000.7	....	+5,832.7	3,577	+2,255.7	3,818.6
1908	17,392	16,368	—1,024	1,848.3	....	+ 824.3	3,586.8	—2,762.5	1,056.1
1909	16,368	18,382	+2,014	2,645	3,511	+8,170.0	3,577	+4,593	5,649.1
1910	18,382	16,167	—2,215	2,722	....	+ 507	3,577	—3,070	2,579.1
1911	16,167	19,494	+3,327	2,709	1,600	+7,636	3,577	+4,059	6,638.1
To July 1, 1912	19,494	18,207	—1,287	1,147	....	— 140	1,783.6	—1,923.6	4,713.5

Average safe yield—9.8 M. G. D.

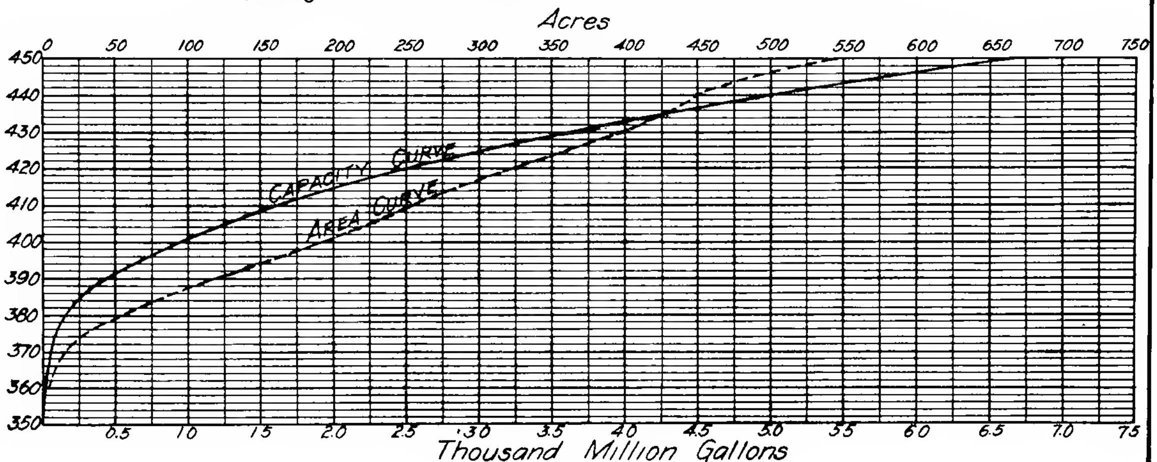
SAN ANDRES RESERVOIR

Capacity and Area

Contour Elevation	Area in Acres	Capacity in MG
350	0.00	0.00
360	2.87	4.68
370	13.74	31.74
380	55.78	145.02
390	119.21	430.12
400	179.95	917.56
410	255.16	1626.47
420	324.79	2571.37
430	394.63	3743.48
440	458.68	5133.75
450	549.00	6773.75

Crest of Dam - Elev 449.5'
Max. Ht of Water .. 446.25'
Capacity - 6,229,524,000 Gals.

Outlet Elev. 376.5'
0 on Gauge 360.0'



Calculations from Map F-20

Crystal Springs Datum.

From Records of S.V.W. Co.
Drawn by A.J. Krutmeyer S.V.W.Co.
Compared & Checked by H. Tunnit S.V.W.Co

SPRING VALLEY WATER CO.
San Francisco.
July-1912

Anderson C-5

The San Andreas Reservoir occupies a commanding position ten miles from San Francisco.

Safe Continuous Yield of San Andreas Reservoir is 5.5 M. G. D.

The records for this reservoir go back as far as 1871, excepting for the year 1889, in which the record is lost. For that year the draft reported in the Municipal Report for 1901-02, p. 793, has been accepted.

The records have been subjected to detailed examination and the tabulation represents the

TABULATION OF PERFORMANCE—SAN ANDREAS RESERVOIR.

	SPRING VALLEY WATER COMPANY RECORDS.					ESTIMATED PERFORMANCE.			
	In Storage First of Year. M. G.	In Storage End of Year. M. G.	Gain. M. G.	Total Draft. M. G.	Total Inflow. M. G.	Estimated Draft. M. G.	Remainder. M. G.	In Storage End of Year. M. G.	Remarks. M. G.
1871............	1,120	1,484	+ 364	1,109	+1,473	2,007.5	— 534.5	585.5	
1872............	1,484	3,351	+1,867	1,541	+3,408	2,013.0	+1,395.0	1,980.5	
1873............	3,351	2,841	— 510	1,798	+1,288	2,007.5	— 719.5	1,261.0	
1874............	2,841	3,165	+ 324	1,877	+2,201	2,007.5	+ 193.5	1,454.5	
1875............	3,165	2,279	— 886	2,314	+1,428	2,007.5	— 579.5	875.0	
1876............	2,279	3,160	+ 881	2,825	+3,706	2,013.0	+1,693.0	2,568.0	
1877............	3,160	521	—2,639	2,608	— 31	2,007.5	—2,038.5	529.5	
1878............	521	2,851	+2,330	2,173	+4,503	2,007.5	+2,495.5	3,025.0	
1879............	2,851	2,880	+ 29	2,779	+2,808	2,007.5	+ 800.5	3,825.5	
1880............	2,880	4,371	+1,491	2,829	+4,320	2,013	+2,307	6,132.5	
1881............	4,371	4,073	— 298	3,074	+2,776	2,007.5	+ 768.5	6,901.0	Surplus
								6,230.0 (b)	+671 to C. S.
1882............	4,073	1,887	—2,186	3,318	+1,132	2,007.5	— 875.5	5,354.5	
1883............	1,887	562	—1,325	1,861	+ 536	2,007.5	—1,471.5	3,883.0	
1884............	562	1,481	+ 919	2,068	+2,987	2,013.0	+ 974	4,857.0	
1885............	1,481	1,109	— 372	2,137	+1,765	2,007.5	— 242.5	4,614.5	
1886............	1,109	2,737	+1,628	738	+2,366	2,007.5	+ 358.5	4,973.0	
1887............	2,737	1,810	— 927	2,026	+1,099	2,007.5	— 908.5	4,064.5	
1888............	1,810	738	—1,072	2,388	+1,316	2,013.0	— 697.0	3,367.5	
1889............	738	3,867	+3,129	1,019 (a)	+4,148	2,007.5	+2,140.5	5,508.0	
1890............	3,867	5,236	+1,369	801	+2,170	2,007.5	+ 162.5	5,670.5	
1891............	5,236	4,530	— 706	1,163	+ 457	2,007.5	—1,550.5	4,120.0	
1892............	4,530	4,558	+ 28	1,198	+1,226	2,013.0	— 787.0	3,333.0	
1893............	4,558	4,348	— 210	1,724	+1,514	2,007.5	— 493.5	2,839.5	
1894............	4,348	5,220	+ 872	1,598	+2,470	2,007.5	+ 462.5	3,302.0	
1895............	5,220	3,656	—1,564	1,999	+ 435	2,007.5	—1,572.5	1,729.5	
1896............	3,656	2,658	— 998	2,423	+1,425	2,013.0	— 588.0	1,141.5	
1897............	2,658	1,785	— 873	2,624	+1,751	2,007.5	— 256.5	885.0	
1898............	1,785	752	—1,033	2,049	+1,016	2,007.5	— 991.5	—106.5	
1899............	752	2,012	+1,260	407	+1,667	2,007.5	— 340.5	—340.5	
1900............	2,012	1,702	— 310	2,207	+1,897	2,007.5	— 110.5	—110.5	
1901............	1,702	400	—1,302	3,053	+1,751	2,007.5	— 256.5	—256.5	
1902............	400	521	+ 121	2,146	+2,267	2,007.5	+ 259.5	+259.5	
1903............	521	1,038	+ 517	2,380	+2,897	2,007.5	+ 889.5	1,149.0	
1904............	1,038	2,518	+1,480	2,656	+4,136	2,013.0	+2,123.0	3,272.0	
1905............	2,518	1,875	— 643	2,302	+1,659	2,007.5	— 348.5	2,923.5	
1906............	1,875	2,642	+ 767	2,946	+3,713	2,007.5	+1,705.5	4,629.0	Surplus
1907............	2,642	4,406	+1,764	3,130	+4,894	2,007.5	+2,886.5	7,515.5	1,285.5 to C. S.
1908............	4,406	2,946	—1,460	3,756	+2,296	2,013.0	+ 283.0	6,230 (b)	+283.0 "
							6,230		
1909............	2,946	4,528	+1,582	3,756	+5,338	2,007.5	+3,330.5	6,230	+3,330.5 "
1910............	4,528	3,830	— 698	3,204	+2,506	2,007.5	+ 498.5	6,230	+ 498.5 "
1911............	3,830	4,249	+ 419	4,162	+4,581	2,007.5	+2,573.5	6,230	+2,573.5 "

Surplus 8642
Less 814

7828 M. G.
Av. = 190.9 M. G. Ann.
0.52 M. G. D.

(a) Records taken from Municipal Report 1901-02.
(b) Reservoir capacity 6230 million gallons—all above that figure is surplus.

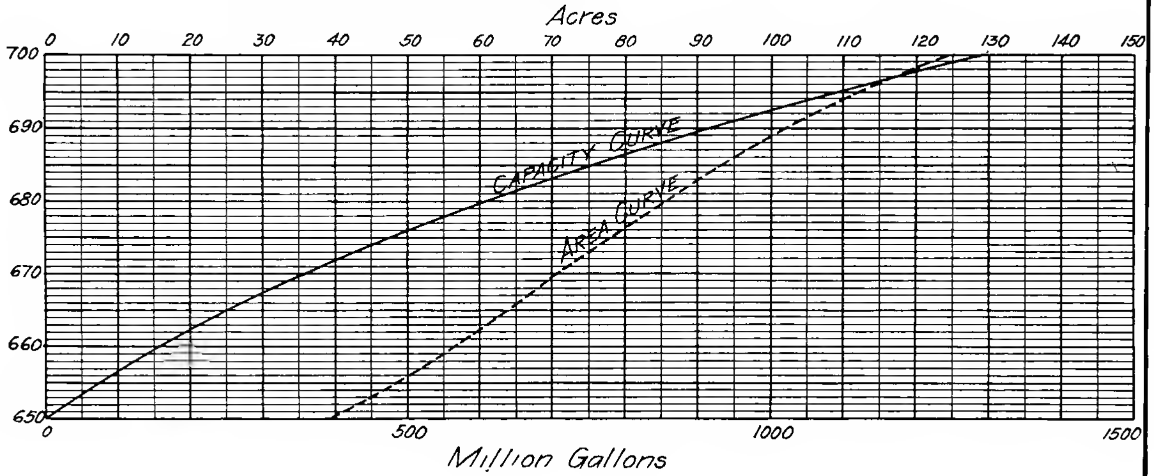
PILARCITOS RESERVOIR

Capacity and Area

Contour Elevation	Area in Acres	Capacity in M.G.
650	38.85	0.00
660	56.13	154.69
670	70.30	360.59
680	86.04	615.21
690	102.84	922.83
700	124.99	1293.87

Crest of Dam - Elev. 698.75'
Max. Ht. of Water Elev. 696.75'
Capacity - 1,083,000,000 Gals

Outlet Elev - 650.75'
0 on Gauge " 650.75'



Calculations from Map F-18

Crystal Springs Datum.

From Records of S.V.W.Co
Drawn by ..... A.J.Krutmeyer .... S.V.W.Co
Compared & Checked by H. Imrutt S.V.W.Co

SPRING VALLEY WATER Co.
San Francisco.
July - 1912

Anderson C-6

PILARCITOS RESERVOIR LIES IN A REGION HEAVILY TIMBERED AND OF HIGH RAINFALL.

conditions under operation in the same manner as described for Crystal Springs Reservoir.

Maximum capacity of San Andreas Reservoir is 6,230 million gallons. Full reservoir would be reached in 1881, and the surplus of 671 million gallons would either be stored directly in Crystal Springs Reservoir, or the draft from San Andreas increased and from Crystal Springs decreased to utilize this volume, which would otherwise be wasted.

In the four years from 1898 to 1901, both inclusive, there would be deficiency in San Andreas Reservoir to supply the continuous draft established, in amounts as shown on the table, totalling 814 M. G., or 143 M. G. more than had previously been turned over to Crystal Springs

TABULATION OF PERFORMANCE—PILARCITOS RESERVOIR.

	SPRING VALLEY WATER COMPANY RECORDS.					ESTIMATED PERFORMANCE.			
	In Storage First of Year. M. G.	In Storage End of Year. M. G.	Gain. M. G.	Total Draft. M. G.	Total Inflow M. G.	Estimated Draft. M. G.	Remainder M. G.	In Storage End of Year M. G.	Remarks. M. G.
1867	414	522	+108	979a	+1,087	1,095	— 8	406	
1868	522	471	— 51	1,064	+1,013	1,098	— 85	321	
1869	471	511	+ 40	1,177	+1,217	1,095	+122	443	
1870	511	301	—210	1,375	+1,165	1,095	+ 70	513	
1871	301	826	+525	578	+1,103	1,095	+ 8	521	
1872	826	788	— 38	949	+ 911	1,098	—187	334	
1873	788	744	— 44	892	+ 848	1,095	—247	87	
1874	744	595	—149	1,229	+1,080	1,095	— 15	72	
1875	595	649	+ 54	1,219	+1,273	1,095	+178	250	
1876	649	395	—254	1,130	+ 876	1,098	—222	+ 28	
1877	395	180	—215	701	+ 486	1,095	—609	— 581	
1878	180	663	+483	1,156	+1,639	1,095	+544	+ 544	
1879	663	781	+118	1,018	+1,136	1,095	+ 41	+ 585	
1880	781	818	+ 37	1,105	+1,142	1,098	+ 44	+ 629	
1881	818	517	—301	1,239	+ 938	1,095	—157	+ 472	
1882	517	246	—271	1,448	+1,177	1,095	+ 82	+ 554	
1883	246	193	— 53	1,501	+1,448	1,095	+353	+ 907	
1884	193	874	+681	1,371	+2,052	1,098	+954	+1,861	Surplus
								1,083b	+778 M. G. to C. S.
1885	874	654	—220	1,544	+1,324	1,095	+229	1,083	+229 M. G. to C. S.
1886	654	368	—286	1,393	+1,107	1,095	+ 12	1,083	+ 12 M. G. to C. S.
1887	368	162	—206	1,435	+1,229	1,095	+134	1,083	+134 M. G. to C. S.
1888	162	711	+549	1,046	+1,595	1,098	+497	1,083	+497 M. G. to C. S.
1889	711	867	+156	968(a)	+1,124	1,095	+ 29	1,083	+ 29 M. G. to C. S.
1890	867	377	—490	1,463	+ 973	1,095	—122	961	
1891	377	456	+ 79	1,267	+1,346	1,095	+251	1,212	+129 M. G. to C. S.
								1,083	
1892	456	713	+257	216	+ 473	1,098	—625	458	
1893	713	626	— 87	1,201	+1,114	1,095	+ 19	477	
1894	626	737	+111	893	+1,004	1,095	— 91	386	
1895	737	258	—479	1,273	+ 794	1,095	—301	+ 85	
1896	258	641	+383	1,270	+1,653	1,098	+555	+ 640	
1897	641	401	—240	1,418	+1,178	1,095	+ 83	+ 723	
1898	401	437	+ 36	236(a)	+ 272	1,095	—823	— 100	
1899	437	710	+273	118(a)	+ 391	1,095	—704	— 704	
1900	710	371	—339	1,451(a)	+1,112	1,095	+ 17	+ 17	
1901	371	276	— 95	1,219(a)	+1,124	1,095	+ 29	46	
1902	276	498	+222	941(a)	+1,163	1,095	+ 68	114	
1903	498	628	+130	1,490	+1,620	1,095	+525	639	
1904	628	344	—284	1,716	+1,432	1,098	+334	973	
1905	344	261	— 83	1,653	+1,570	1,095	+475	1,448	Surplus.
								1,083(b)	+365 M. G. to C. S.
1906	261	193	— 68	1,640	+1,572	1,095	+477	1,083	477 M. G. to C. S
1907	193	206	+ 13	1,596	+1,609	1,095	+514	1,083	514 M. G. to C. S.
1908	206	225	+ 19	1,150	+1,169	1,098	+ 71	1,083	71 M. G. to C. S.
1909	225	417	+192	1,529	+1,721	1,095	+626	1,083	626 M. G. to C. S.
1910	417	224	—193	1,359	+1,166	1,095	+ 71	1,083	71 M. G. to C. S.
1911	224	223	— 1	1,537	+1,536	1,095	+441	1,083	441M. G. to C. S.

Safe yield—3.0 M. G. D.

(a) Records taken from Municipal Report 1901-02.
(b) Reservoir capacity, 1083 million gallons—all above that figure is surplus.

from San Andreas. That net deficiency of 143 M. G. would be withdrawn from Crystal Springs, which, at the end of the period had accumulated, practically a year's supply of the draft from both reservoirs combined.

Subsequently, during 1907, a large surplus would be conveyed from San Andreas to Crystal Springs, and added to annually for the following four years.

The tabulation shows that from San Andreas Reservoir, a continuous safe daily yield of 5.5 million gallons can be developed, with an accumulation of a surplus, after balancing all deficient periods, equal to .52 million gallons per day throughout a period of 41 years.

Pilarcitos Reservoir Will Safely Yield 3 M. G. D.

The records for this reservoir go back as far as 1867—really as far as 1866—in which they are not quite clear and, in 1867, are on file for eight months. In that latter year the draft reported in the Municipal Report for 1901-02 has been accepted, as also in the year 1889, for the same reason as given in the case of the San Andreas Reservoir, and also in the years 1898 to 1902, inclusive, the records of which show some confusion in the amounts drawn directly and solely from the Pilarcitos Reservoir. Some of the same uncertainty exists in the record for 1883, in which the draft as ascertained from the record has been entered in the tabulation.

As with the other reservoirs, the tabulation represents the conditions in the same manner as described for Crystal Springs Reservoir.

The maximum capacity of Pilarcitos Reservoir is 1083 million gallons. Full reservoir is reached in 1884, and, as before, in the San Andreas Reservoir, the surplus of 778 million gallons in that year, and the amounts of surplus in the following years would either be stored directly in Crystal Springs Reservoir, as it is figured in the tabulation, or the draft from Crystal Springs and San Andreas reservoirs decreased, and from Pilarcitos increased to utilize the excess volume which would otherwise be wasted.

Prior to that year 1884, when the reservoir would be filled to its maximum storage, a deficiency of 581 million gallons, on the steady draft of 3 M. G. D., would occur in 1877. An equivalent amount would have been drawn off from either Crystal Springs or San Andreas Reservoir.

Another deficiency occurred in the seasons of 1898 and 1899, in the amounts of 100 and 704 million gallons, and the total of that deficiency would have been drawn from Crystal Springs Reservoir out of the volumes previously turned over to it in the years from 1884 to 1891, inclusive.

The total of the surplus amounts are 1808 M. G. from 1884 to 1891, inclusive, and 2565 M. G. from 1905 to 1911, inclusive, altogether 4373 M. G. while the deficiencies are 581 M. G. in 1877, 100 M. G. in 1898 and 704 M. G. in 1899—altogether 1385 M. G.—leaving a total surplus of 2988 M. G. for the period of 45 years, an annual surplus of 66.40 M. G., or an additional amount of 181,900 gallons per day.

Present Safe Yield of Peninsula System 19 M. G. D.

At the end of the period, the San Andreas and Pilarcitos Reservoirs would be filled to their maximum capacities and Crystal Springs Reservoir to one-third. The combined storage, at the end of 1911, in a total of 13,951 million gallons, would provide for the combined continuous draft from all the reservoirs for more than two years, without any addition from any source.

Summarizing there is—

Crystal Springs Reservoir..	9.8	M. G. D.	safe yield
San Andreas Reservoir....	5.50	"	" "
" " "	.52	"	from surplus
Pilarcitos "	3.00	"	
" "	.18	"	from surplus
Total	19.00	M. G. D.	

From the above amount is to be deducted the quantity required to supply the town of San Mateo and other small communities. That quantity is stated as approximating 600,000 gallons per day. There, therefore, remains a net supply of 18.40 M. G. D. from the Peninsula System available for the City of San Francisco.

It is proper to add, in addition to the quantities of flow considered in the preparation of the foregoing tables, there are records of waste from Pilarcitos, into the ocean, in the early 90's and, later, in the past three years, which have not been incorporated. The total amount, spread over the whole period of 40 to 45 years, would not materially affect the results above.

LAKE MERCED SYSTEM.

The records of pumping from Lake Merced have been carefully examined, with the result of finding the Spring Valley Water Company's records heretofore given substantially correct, wherever the records are in such form as to provide a comparison. In some years, notably from 1898 to 1905, the water pumped from Lake Merced was mingled with that from other sources and it is not now possible to separate the volumes.

The table, comparative, is given below.

LAKE MERCED YEARLY DRAFT IN MILLION GALLONS.

Year.	G. G. Anderson, Corrected.	S. V. W. Co., Records.
1877	281	295
1878	No records.	No records.
1879	No records.	No records.
1880	No records.	No records.
1881	No records.	No records.
1882	No records.	No records.
1883	1,483	1,484
1884	1,354	1,352
1885	1,051	1,048
1886	775	790
1887	1,588	1,588
1888	1,262	1,267
1889	No records.	712
1890	1,254	1,252
1891	233	233
1892	1,245	1,250
1893	655	655
1894	969	970
1895	75	75
1896	No draft.	No draft.
1897	No draft.	No draft.
1898	Records incomplete.	1,127
1899	Records incomplete.	1,330
1900	Records incomplete.	565
1901	Records incomplete.	116
1902	Records incomplete.	1,774
1903	Records incomplete.	1,696
1904	Records incomplete.	1,333
1905	Records incomplete.	1,096
1906	1,257	1,257
1907	1,228	1,228
1908	908	908
1909	1,143	1,143
1910	1,718	1,718
1911	1,120	1,120
1912	721	721

Present Yield of Lake Merced 2.93 M. G. D.

Taking all the years in which the records are available, and in which the various volumes are separated, there is a total pumpage of 20,320 M. G. in 19 years, an average annual pumping of 1069 M. G., or an average of 2.93 M. G. per day.

Accepting the original statements of the Spring Valley Water Company's records, in those years, for which there is no separate statement, there is a total of 30,069 M. G. pumped in 28 years, an average annual volume of 1073.9 M. G., or 2.94 M. G. per day.

Other Systems Not Investigated.

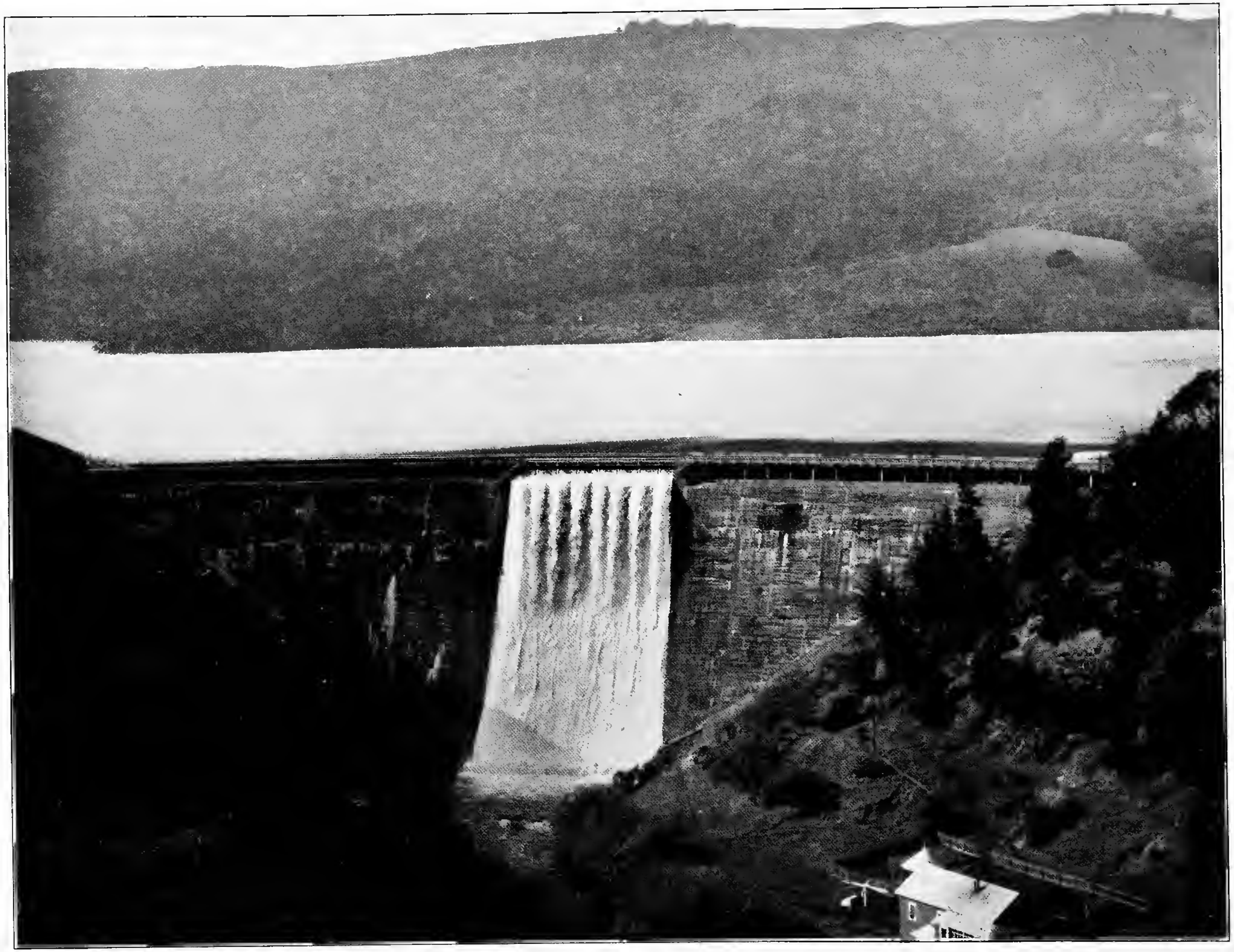
In addition to the water systems mentioned in preceding chapters, the Company owns extensive lands and water rights from which water supply of use for San Francisco can be developed.

At this time I have not investigated the amount of water that can be developed and the conclusions here shown of water resources concern only the Alameda, Peninsula and Lake Merced Systems.

PESCADERO AND SAN GREGORIO CREEKS.

A further productive source of water supply exists in the streams, principally from the Pescadero and San Gregorio Creeks. Part of the run-off from these can be diverted directly to the Crystal Springs Reservoir by gravity conduit, and balance stored in Pescadero Reservoir, and thence pumped to the conduit leading to the Crystal Springs Reservoir. Such combination permits of the utmost conservation of the available water supply. Rainfall records maintained for seventeen years show a relatively high precipitation, and stream gagings for seven years, on a portion of Pescadero Creek within the period of generally low rainfall and run-off, show greater yield per square mile than the Pilarcitos and San Andreas drainage areas. Investigations of and conclusions from these records have not been fully completed by me, but preliminary consideration and study indicates that a very large addition to the dependable water supply of the City can be secured from these nearby sources. To them, in my opinion, much importance attaches, and their value ought not to be overlooked, as may readily be the case by superficial examination. (The Water Company maintained a gaging station and measured the stream flow from 1886 to 1906. Unfortunately the records, with the exception of those referred to above, were destroyed in the fire of 1906.) Respectfully submitted,

GEORGE G. ANDERSON.



CRYSTAL SPRINGS DAM AND RESERVOIR.

The height of this dam can be readily increased to provide storage of 63,000 million gallons. The view was taken in February, 1911, a season of about normal rainfall.

REPORT ON THE DEVELOPMENT OF GROUND WATERS OF THE LIVERMORE VALLEY

BY

WM. MULHOLLAND,

Chief Engineer of the Los Angeles Aqueduct.

AND

J. B. LIPPINCOTT,

Assistant Chief Engineer of the Los Angeles Aqueduct.

San Francisco, Cal., February 2, 1912.

S. P. Eastman, Esq., Vice-President and Manager Spring Valley Water Co.

Dear Sir:

In 1907 a report was written by Mr. Fred H. Tibbetts, Civil and Hydraulic Engineer, on the artesian basin of the Livermore Valley. This report was prepared for the plaintiffs in a certain suit against the Spring Valley Water Company, which suit was dismissed because of the purchase by the Spring Valley Water Company of the plaintiff's lands, including all physical data collected by them. The investigations by Mr. Tibbetts extend from September, 1905, to April 1st, 1908. He made a very exhaustive collection of data concerning the underground water of the Livermore Valley, including the region near Pleasanton, and his report is worthy of careful study

Seepage Into Gravels.

Particular attention is called to his Plate No. 6, which shows the fluctuation in the water plane of the valley between the wet and dry seasons of the year. He states on page 54: "The first (stream) measurements on Jan. 14, 1906, were about 18 hours after the first flood of the season had commenced. The measurements at the Cresta Blanca Bridge showed a discharge of about 1136 cu. ft. per second. At the Pleasanton Bridge a discharge of about 600 cu. ft. per second. The seepage loss indicated was 536 cu. ft. per second, or over 47%." Corresponding to this loss, Well No. 13, which is located just north of Pleasanton, showed an immediate rise of between 4 and 5 feet. The total rise in this well up to April 14th was 10 feet. This shows a large discharge into the gravel bed, and a very prompt response on the part of a well in the central portion of the valley under the so-called "clay-cap". Many other wells could be referred to during the period of Mr. Tibbetts' observation showing similar results.

Velocity of Underflow.

Another portion of Mr. Tibbetts' report of particular interest is his determination of the velocity of underflow in the sands and gravels of the valley floor. He made these determinations at four different localities distributed over the valley, and found velocities ranging from 10.9 feet per day to 57.1 feet per day. His method of determining velocity is known as the "Schlichter" method. This method is recognized as scientific, and a complete description of it may be found in Water Supply and Irrigation Papers Nos. 67, 140 and 112, issued by the U. S. Geological Survey. These velocities are unusually high. This method when applied to the Narrows of the Los Angeles, San Gabriel and Mojave Rivers in Southern California, showed underflow in these granitic materials ranging from 10 to 20 feet per day.

Productivity of Alameda System.

Mr. Hermann Schussler, Consulting Engineer for the Spring Valley Water Company, has directed the measurements of the flow of Alameda Creek at the Sunol Dam, beginning with the season of 1889-90 to 1907-08, inclusive. He found a mean flow of 132.8 M. G. D., which he distributes as 48 M. G. D. coming from the Pleasanton region, and 84.8 M. G. D. as coming from the Alameda Creek region. This table, in detail, is in the files of the Spring Valley Water Company. In Mr. Schussler's report of November 14, 1911, on page 27, he gives the average annual run-off for the Pleasanton region for a period of 19 years as 17,579 M. G. per year, or practically 48 M. G. per day. This amount he considers as available for storage in the gravel beds of the Livermore Valley, provided the proposed Arroyo Valle Reservoir is utilized in the manner he outlines.

Dr. J. C. Branner, in his report dated December 1, 1911, has presented a very complete and interesting geological study of the Livermore Valley and its tributary drainage basins, including the "recent" formation in the valley fill. The logs of wells collected by Dr. Branner, Mr. Tibbetts and the Spring Valley Water Company have all been studied, and the wells have been located on suitable maps, so as to give the most comprehensive idea of this valley fill. In addition to the above, Mr. F. C. Herrmann. Chief Engineer of the Spring Valley Water Company, has taken great pains to supply all information possible that has been requested, and has spent ten days' time in the field in locating the points of interest, and furnishing other important data. Mr. F. W. Roeding, Superintendent of the Agricultural Department, has also spent two days in the field with us in going over physical conditions. The field investigations which we have made have covered nearly two weeks' time, and have extended in detail over the valley into the drainage basin of Calaveras Creek and into the upper portions of the water supply as far as Mt. Hamilton. In short, we have utilized all available data and have made an exhaustive personal examination of the situation.

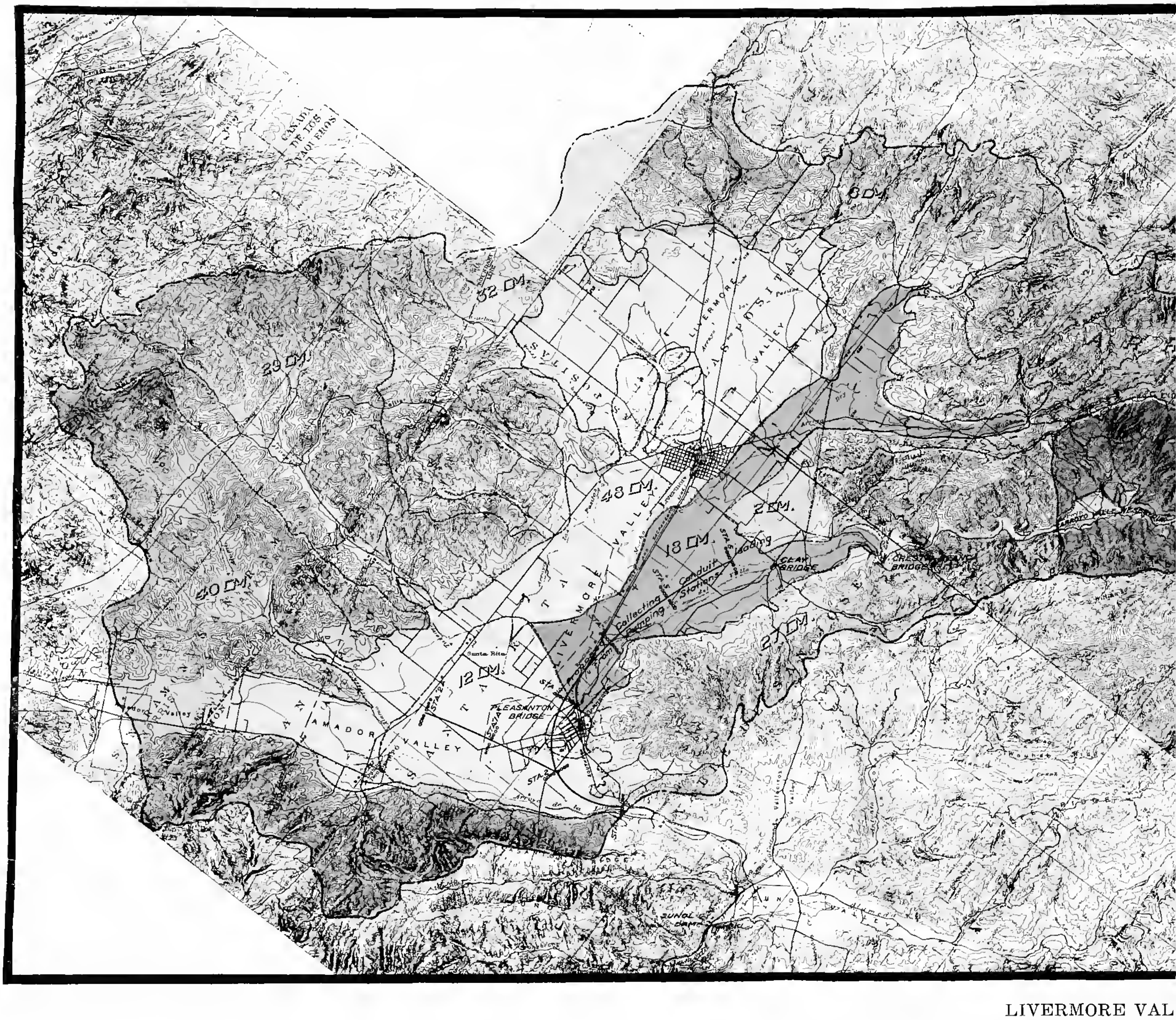
Rainfall and Run-off.

Table No. 1 shows the estimated rainfall in various portions of the drainage basin, the areas in square miles of these various sections, and the run-off in million gallons per day which is estimated for each section.

Mr. C. E. Grunsky, in a paper contributed to the American Society of Civil Engineers (Vol. 61, No. 1090, Plate 59), estimates the rainfall of the southerly portion of the drainage basin tributary to the Livermore Valley as about 24 inches. Haehl and Toll, in the same volume, Plate 60, estimate the rainfall for this district at about 19 inches. Mr. Hermann Schussler considers this rainfall in detail for a period of four years, extending from 1904-5 to 1907-8, for this southerly portion of the basin, this data being given in his report of August, 1911. We have made allowance for this period being above the normal in precipitation, which would indicate a rainfall of about 20 inches.

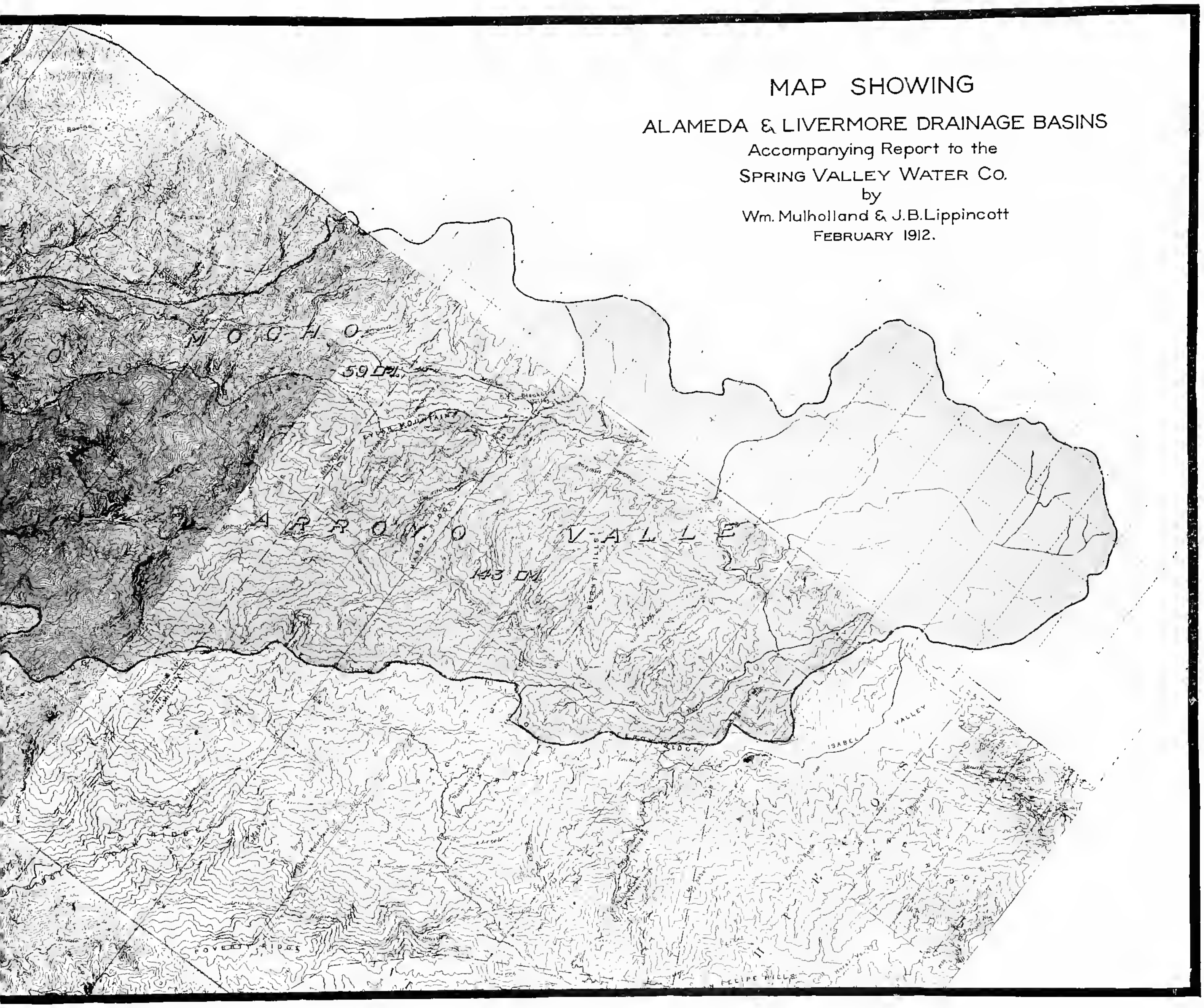
There is an old rainfall record at Mt. Hamilton, beginning in 1881 and averaging 31.5 inches. This is on the headwaters of Calaveras Creek, but near the head of the Del Valle, the elevation being 4209 feet. The rainfall record at Livermore was started in 1871, and shows a mean to date of 15.46 inches. The elevation of Livermore is 485 feet, and it is situated in the middle of the valley under consideration. The mean rainfall between Mt. Hamilton and Livermore is 23.65 inches, which has been accepted by a number of engineers as applicable to the portion of the basin south of the Livermore Valley. After considering all this data, and making a personal examination of the vegetation in the various drainage basins, the precipitation as shown in Table 1, for the various parts of the entire drainage basin was arrived at.

The U. S. Geological Survey since 1895 has been measuring the flow from a large number of drainage basins in California and collecting all available rainfall records in these drainage basins. They have also assembled all other available information concerning rainfall and run-off which has been collected by other engineers in this State. This has extended the work previously done by the California State Engineering Bureau along similar lines. In Water Supply Paper No. 81 of the Geological Survey, entitled "California Hydrography", on page 17 is given a general curve for large watersheds, which is intended to represent general or average conditions in California. It is recog-



LIVERMORE VAL

The run-off from this area replenishes



)RAINAGE BASIN.
ıderground supply of Livermore Valley.

nized that there is a wide variation in the ratio of run-off to rainfall, due to the character of the storm and of the drainage basin. No fixed relation exists, but this general curve is believed to as closely represent average conditions as can be stated. It is the result of the investigations of the Geological Survey extending over a decade. This curve has been used in computing the run-off for the various portions of this drainage basin, as given in Table No. 1.

Table No. 1 divides the run-off from the Livermore basin into two portions, 40.3 M. G. D. being discharged onto or over the 18 square miles of valley floor where sand and gravel appear at the surface, and where the water would be readily absorbed. 11.2 M. G. D. are discharged upon other portions of the valley floor where the soil is more dense, and where the water would not be so readily absorbed. The total estimated discharge from the basin is 51½ M. G. D.

Productivity of Livermore Valley.

The water lost by evaporation does not appear in the volume measured at the Sunol Dam. The amount given as coming from the Pleasanton region during the 19 year period above mentioned as measured at the Sunol Dam, was 48 M. G. D. If to this were added evaporation losses from the wet lands, the amount given by Mr. Schussler would fully confirm the 51.5 M. G. D. estimated in Table 1.

TABLE NO. 1.

Rainfall and run-off of the Pleasanton region above the Narrows:

Portion of Basin.	Rain Inches.	Area Sq.Miles.	Run-off M.G.D.	
Arroyo Valle above Reservoir	25	143	25.6	
Arroyo Mocho	20	59	6.3	
Southerly foothills below Arroyo Valle Reservoir and to Narrows	20	27	2.9	
Valley floor with sand and gravel cover	15.46	18	4.7	
Patterson Pass region east of Livermore	18	8	0.7	
Low hills southeast of Livermore	16	2	0.1	
Total tributary to gravel beds		257	40.3	40.3
Alamo Basin and hills on west side of valley	20	40	4.3	
Tassajero Basin	20	29	3.1	
Positas Basin	18	32	2.9	
Valley floor with clay and soil cover	15.46	48	0.9	
Total tributary to other portions of basin		149	11.2	11.2
Grand total		406		51.5

Evaporation Losses.

The official map of Alameda County of 1874 shows a lagoon in the southwest portion of the Livermore Valley extending in an irregular manner from the narrows toward Santa Rita, and covering an area of 8 square miles. A photograph of this map is given as Map 2 in Mr. Schussler's report of Nov. 14, 1911. A study of the logs of the wells in the valley, and a field inspection of the lands in question, indicates that over an area of 12 square miles, the water now stands at an average depth of not to exceed 3.0 feet from the surface. An extended series of observations of evaporation from similar moist lands has been made under our direction in Owens Valley during the past two years. These observations are fully described in Engineering News, October 12, 1911, page 430. It is here shown that with the water plane 3.0 feet from the ground surface, the evaporation is 55 per cent of that from a water surface in that locality, $\frac{37''}{(67.24'')}$. The evaporation from a water surface in the Livermore Valley is taken as 40″, 55% of which is 22″, or 1.83 feet in depth. This evaporation over an area of 12 square miles is equivalent to a loss of 12 M. G. D. for a year. A second and independent estimate of this wet area and depth of water plane was made by Mr. F. W. Roeding, who is very familiar with the valley, which classification confirms the above estimate.

Geological Conditions Favorable to Productivity.

The mean depth of all wells in the valley is 76 feet. The logs of *all* the wells in the valley indicate that 28 per cent of their depth is in sand and gravel. The logs of the wells over 100 feet in depth indicate that there is as much gravel in the first 100 feet as at greater depths. South of the Southern Pacific line between Pleasanton and Livermore, the sands and gravels predominate at the surface, but northwesterly of Pleasanton, the clays predominate at the surface. These sands and gravels have at least 35% of voids that may be drained, or 10% of the mass of the valley fill. The clays or denser soils which constitute the remaining 72% of the wells, as indicated by their logs,

while they have as high a percentage of voids will not be capable of such free drainage, but if the gravels underlying them are drained, it is believed that these denser soils will give up 10 per cent of their volume in water, or 7 per cent of the mass of the valley fill. The total amount of water, therefore, that can be withdrawn from these soils is considered as 17% of the mass. With 24 square miles capable of being drained, there is a capacity of 2611 acre feet per foot of depth of the valley, and to find storage for 40.3 M. G. D. for a period of one year, the water plane of the 24 square miles must be lowered 18 feet, or if the storage must be provided for 51½ M. G. D., it must be drained 23 feet in depth.

The records of flow at the Sunol Dam indicate that the minimum year run-off is 18 per cent of the mean; therefore, if storage is to be provided sufficient to carry by one dry year on the basis of 40.3 M. G. D. being stored, we must be prepared to lower the water plane 31 feet, and if we are to provide similar storage for 51.5 M. G. D. we must be prepared to lower it 40 feet.

Seepage Observations.

On January 26, 1912, a storm occurred during the period of our field inspection. On January 27th at 10 a. m. we witnessed a flow of 45 second feet (29 M. G. D.) at the Clay Bridge on the Arroyo Valle all sink into the gravels in 3,000 feet of chanel below the bridge. This is given as indicative of the rapidity with which the gravels of the valley will absorb the flood waters. Mr. Tibbetts found a much larger absorption with a larger flood.

At the same time there was 10 second feet (6.5 M. G. D.) flowing in the Mocho at the mouth of Dry Creek. This all sank within one mile. The Positas Creek was flowing on January 2, 1912, normally before the storm, at the bridge 1½ miles northwest of Livermore 2.2 second feet (1.4 M. G. D.), and at its junction with the Mocho five miles below, 1 second foot (.64 M. G. D.). This channel is in the heavy soils of the northern side of the valley, where seepage losses are much lower.

Physical Conditions of Livermore Valley.

Having now considered the precipitation on the mountain area tributary to the Livermore Valley, and the probable amount of run-off that will reach it from these sources, we will review the physical condition of the valley itself with special regard to its adaptability to act as a reservoir to arrest the more or less intermittent flow of the streams as they debouch on their channels in the valley floor.

The valley floor is one of flat relief, and comparatively low gradient, and the fact that the larger of the streams entering it come in at points fairly wide apart, and are compelled to flow by way of the longer axis of the valley, each for the greater portion of the distance in its own rather rambling course to reach the exit, makes the conditions for the absorption of their waters peculiarly favorable.

The material borne down by the floods of both the Arroyo del Valle and the Mocho consists of gravel of a wide range of texture, the fragments of which are generally more spheroidal in form than the usual sub-angular shape of granite debris, and hence afford a mass both more capacious as to voids, and more easily permeated by water than granite gravel. This condition will account for the remarkably high velocities observed in the sub-flow by Mr. Tibbetts. The most casual glance at the present surface conditions of the valley, even without the disclosures of the well logs, shows that both the Mocho and Arroyo Valle streams have wandered in a broad range north and south during the period covered by the process of filling the valley to its present level, and indeed have furnished by far the greater portion of the material of the southerly portion of the fill. Since this material was transported entirely during periods of high flood flow, it is mainly composed of clean materials, as the finer products of erosion were carried away in suspension to the sea.

The area embraced in the northerly and northeasterly slopes of the watershed comprises a region radically different in character of surface from the basins of the Mocho and Arroyo del Valle. The hill slopes of this area, instead of being rugged and broken, are smooth of contour, and present the aspect of mature topography, and hence at the present time, geologically speaking, yield little or no gravel debris. The weathering of this surface in its present form has spread a broad tapering mantle of soils quite dense in character southerly into the valley overwhelming somewhat the earlier de-

posits of the eastern streams, and in all probability blanketing coarser deposits of earlier times from its own slopes. This assumption is supported by the log of well No. 42 (the location of which is too far north to reasonably presume of the swing of the Mocho that far north), which penetrated gravel amounting to 23% of its total depth of 130 ft., and which from its position would lead to the inference that the gravel so found was in the old debris fan of Tassajero Creek.

Swamp Area.

From Santa Rita westerly to Dublin, and for a very considerable distance north of the road, between these two points, and ranging in fact quite well up into the San Ramon flats, the ground is observed to be in a state of almost complete saturation, and the nature of the plant life indicates that this is a permanent condition. This condition also extends southerly almost to the producing wells of the Spring Valley Water Company, situated southwest of Pleasanton, and has every appearance of being due to true artesian forces. While it is reasonably certain that this condition of pressure on the southerly portion of this wet area is due to the sub-flow of the Mocho and Arroyo Valle streams we cannot reasonably attribute this condition in the northerly portion of the area to these streams, and hence the theory here presented that the water appearing at this point has its origin on the slopes of the Tassajero, Alamo and San Ramon basins. The water yielding possibilities of the district are dwelt on here at length for the reason that it seems to have been somewhat minimized or even ignored in prior reports. The soil cover of this district has been referred to as being dense in character. It does not follow, however, that density and impermeability are altogether analogous terms. These soils have been referred to in other reports as clays, and while it is conceded that they are of a clayey composition, it is not admitted that they are impermeable, else how does the water that manifestly uprises from beneath them reach the surface? In point of fact, this deposit has been laid down in the usual manner of the building up of all aluvial deposits, layer by layer, year by year, in exceedingly small increments remaining always covered by a vegetable growth, the dying roots of each generation of which leave the soil penetrated by pores of dead rootlets and vermiculated by the work of worms. This organically created texture is quite common in heavy soils, as is well known to engineers who have had much to do with building dams or other embankments, and who invariably find in dealing with this kind of material that it makes a less volume in the fill than is accounted for in the borrow pit due to the breaking down of this structural porosity.

This deposit, therefore, instead of presenting an unabsorptive impassable barrier to water, affords a fairly receptive and very rentemtive sponge, that without doubt, materially adds to the water resources of the valley, and that will readily yield its precious burden when the gravels, that in all probability are just beneath it, are tapped by wells to drain it. In another portion of this report, the amount of water lost by evaporation off this area is mentioned, and with proper means of development this great loss is altogether preventable and wholly recoverable. It is unfortunate that no wells exist in the northerly portion of this region, but it is fairly certain that quite extensive gravel beds, the product of the erosional effect that in time past smoothed the contour of the hills to the north, exist beneath the clayey soil cover. This is especially likely in the vicinity of the mouths of the drainage lines. It is also probable that the fault offset in the bed rock floor of the valley following parallel to the base of the Pleasanton Ridge contains deep seated gravel deposits that if tapped would sub-drain the broad area to the north.

Other Soil Characteristics and Stratigraphical Features.

The region lying east and south of Livermore has a cover of light gravely soil and probably contributes a very considerable percentage of the precipitation on it to the ground water. It is probable that below the soil cover in this region the whole valley fill to the bed rock consists of coarse gravel and boulders. Farther down the valley the well logs show the usual characteristics of deposit of all inclosed California mountain valleys, namely, alternating sandy clays and gravels, the clays occurring in lenticular tongues irregularly imbricated, and occupying perhaps what at the time of their

deposit were the fragments of abandoned channels forming mud-collecting sloughs.

All the streams entering the valley unite to form Laguna Creek, which, flowing through the neck of the valley, enters the Sunol Valley where it joins Alameda Creek.

Development of Sunol Valley.

At the time of the visit, the observations of which form the basis of this report, there was a stream of nine or ten second feet in Laguna Creek, and from surface conditions it appeared that it would be a comparatively easy matter to conserve such flows as this if they are of common occurrence by compelling the water to flow in a canal around the edge of Sunol Valley.

Observations made along the banks of the Alameda Creek in the Sunol Valley indicate that the stream is at present a cutting one, and also seems to indicate that in the past it meandered freely from one side to the other, laying down gravel beds which will probably be found co-extensive with the whole flat valley area. Inexpensive borings or excavations would easily determine if this were the case, and, if so, the canal suggested would prove a very effective sink for the storage of whatever surplus water came down Laguna Creek during periods of excessive influx of water to the gravel beds of the Livermore Valley. Water stored in this manner would all be recoverable by the filter gallery now existing, and the water developed by this gallery could be very much augmented in times of scarcity by the simple device of wells bored through the gravels along the line of the gallery and operated by compressed air from a central station.

Development in Livermore Valley.

This method of development is also the one suggested and recommended for the recovery of the water stored in the Livermore Valley. A gallery such as the one at Sunol might be constructed to follow the thread or thalweg of the valley, and having a flatter grade than the valley, hence obtaining a greater depth below the surface at the upper end, but it must be remembered that such a method of development would not be subject to control as to outflow, as it would prove to be too deep during times of abundance and too shallow during times of scant supply. A better method would be to lay a conduit near the surface following the thread of the valley and having groups of wells arranged in lines transversely to it, these groups being disposed at intervals of say a mile and a half to two miles apart and each group being operated by an air compressor stationed thereat. By this system it would be possible to follow a receding water plane to great depths in times of drought. This method is one very much in vogue in Southern Claifornia, and is found both efficient and effective for its purpose. The limits of depth to which centrifugal pumps will draw water would make them incompetent tools for this service as years may come in which it may be necessary to draw water from greater depths than would be attainable by their means. The computation of the volume of the prism of recoverable water in the Livermore Valley, given in another portion of this report, contemplates its withdrawal to a depth of 18 feet below the natural water plane, and assumes that as being the average depth year by year, but, by the installation and use of the compressed air method of pumping, much greater depths can be voided when there comes the occasional, inevitable dry year, making the addition of possibly 50 to 60% of the amount of water computed for the 18-foot depth.

Suggestions for Operation.

It is suggested that the order of operation of these plants should be such that the lower one, which should be located in the upper constriction of the valley's neck, be used for continuous operation so as to maintain depletion to avoid waste by natural overflow. The next ones to be operated should be successively from the upper end in order to prepare exhausted space in the first and most receptive portion of the gravel mass and which is naturally the main recharging area of the debris prism of the valley.

A branch line conduit, with perhaps two groups of wells, should also be built northerly to tap the extensive semi-swamp area that exists in that direction.

The whole problem of development, however, is so simple that suggestions as to detail are superfluous here, as they will readily suggest themselves to the engineers of the Spring Valley Company.

Conclusions.

The Livermore Valley, like all valleys of its type, possesses the great natural advantage of having the most receptive mass of its fill where the water enters it, but this valley is exceptionally favored in this particular, as there are contributions at intervals all around it and the run-off is retarded by the flatness of the valley slope. Moreover, the avidity of absorption is wonderful, as one of the available observations records the disappearance during a freshet of moderate flow of 536 second feet from the Arroyo Valle wash in a distance of less than six miles. Another great advantage lies in the fact that the greater streams have to traverse the valley by the longer distances and necessarily over the more porous courses.

In its salient features the joint mountain and valley area bears a marked similarity to the San Fernando watershed which supplies the City of Los Angeles with an average yield of 50 M. G. D.

Notwithstanding the ample provision naturally existing for the absorption and storage of the drainage tributary to the Livermore Valley there still remains the necessity of artificially providing for the impounding of the peaks of extreme floods. The construction of the proposed reservoir in the Arroyo Valle canyon would seem to be ample for this purpose, as its computed capacity would yield a flow of 37.7 M. G. D. for a period of one year with a height of dam of 150 feet. This great volume would possibly be sufficient to regulate anything but the floods of very rare occasions, and serve to remedy whatever deficiencies exist in the valley itself as a medium of storage. Taking the whole watershed, embracing mountain and valley, its perfection as a unit for the purpose of a water supply must be regarded as unique, as all the necessary elements of catchment area, conservation capacity and sanitary protection are joined in one harmonious whole. One cannot help but admire the wisdom and foresight that suggested its possession and control for this purpose, and the acquisition of this property is one of marked advantage, not alone to the Spring Valley Water Company, but to the whole population it will ultimately serve and to whose use it will be perpetually dedicated.

We would recommend deferring the construction of the Arroyo Valle Reservoir until after the underground development of the Livermore Valley has been perfected and more exact data is obtained relative to the stream flow and drainage therein. Only with this information can the correct height of dam be determined.

We believe that by following the suggestions above outlined, and without the construction of the Arroyo Valle Reservoir, from 35 to 40 M. G. D. continuous flow can be developed from the gravel beds of Livermore Valley. With the Arroyo Valle Reservoir, this amount may be made to closely approximate the full mean annual water crop of the drainage basin, estimated at 51.5 M. G. D. continuous flow.

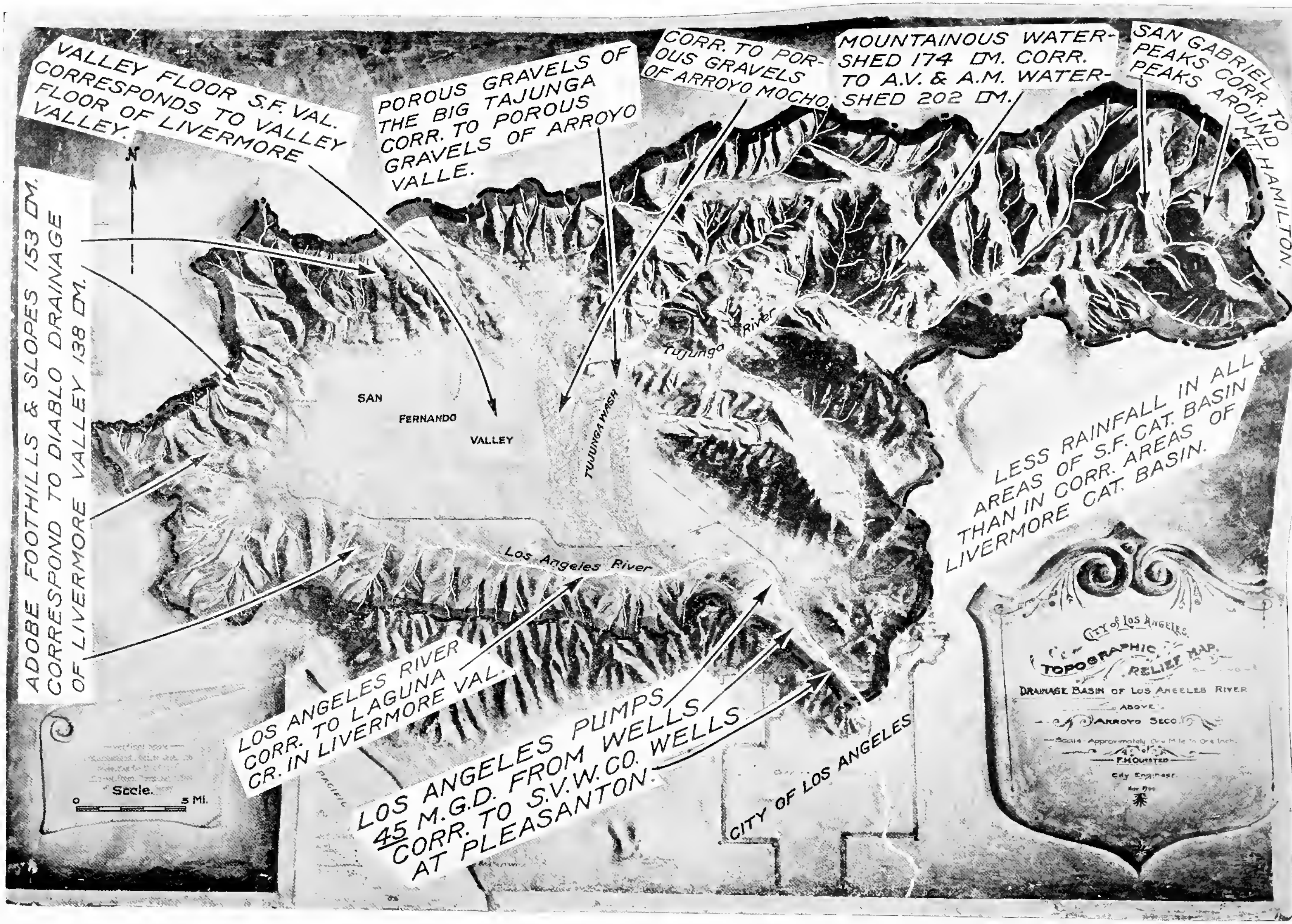
Respectfully submitted.

WM. MULHOLLAND,

J. B. LIPPINCOTT,

Consulting Engineers.

CONDITIONS OF SAN FERNANDO VALLEY AND WATERSHED ARE ALMOST IDENTICAL WITH THOSE OF LIVERMORE VALLEY.



Livermore Valley has { greater Rainfall in all parts, larger mountainous area, larger gravel beds, less adobe foothill area, } than the San Fernando Valley.

THE FUNDAMENTAL CONDITIONS OF SAN FERNANDO VALLEY FROM WHICH LOS ANGELES RECEIVES ITS ENTIRE WATER SUPPLY ARE PARALLEL TO THOSE IN THE LIVERMORE VALLEY

BY

WM. MULHOLLAND,
Chief Engineer of the Los Angeles Aqueduct,

AND

J. B. LIPPINCOTT,
Assistant Chief Engineer of the Los Angeles Aqueduct.

Los Angeles, Cal., May 13, 1912.

Mr. S. P. Eastman, Manager Spring Valley Water Company,
San Francisco, California.

Dear Sir:

You have requested a statement of the extent of underground water development in Southern California. This is a very broad subject. Concisely put, there is twice as much water supplied from underground sources for both irrigation and domestic uses as is supplied from surface streams. The largest city of Southern California, Los Angeles, and all its suburbs, Pasadena, Hollywood, Santa Ana, Long Beach and the other beaches, are so sustained, having a total population of half a million souls. The total summer surface flow of all our Southern California streams is about 250 second feet, while in 1904 the estimated developed supply was 500 second feet. Since that time the underground development has increased. In some instances this has gone too far, while in others, our recent cycle of wet years has restored the depletion of the seven dry years ending with 1900.

The drainage basin of the Los Angeles River above the Narrows closely resembles the Livermore Valley above Verona.

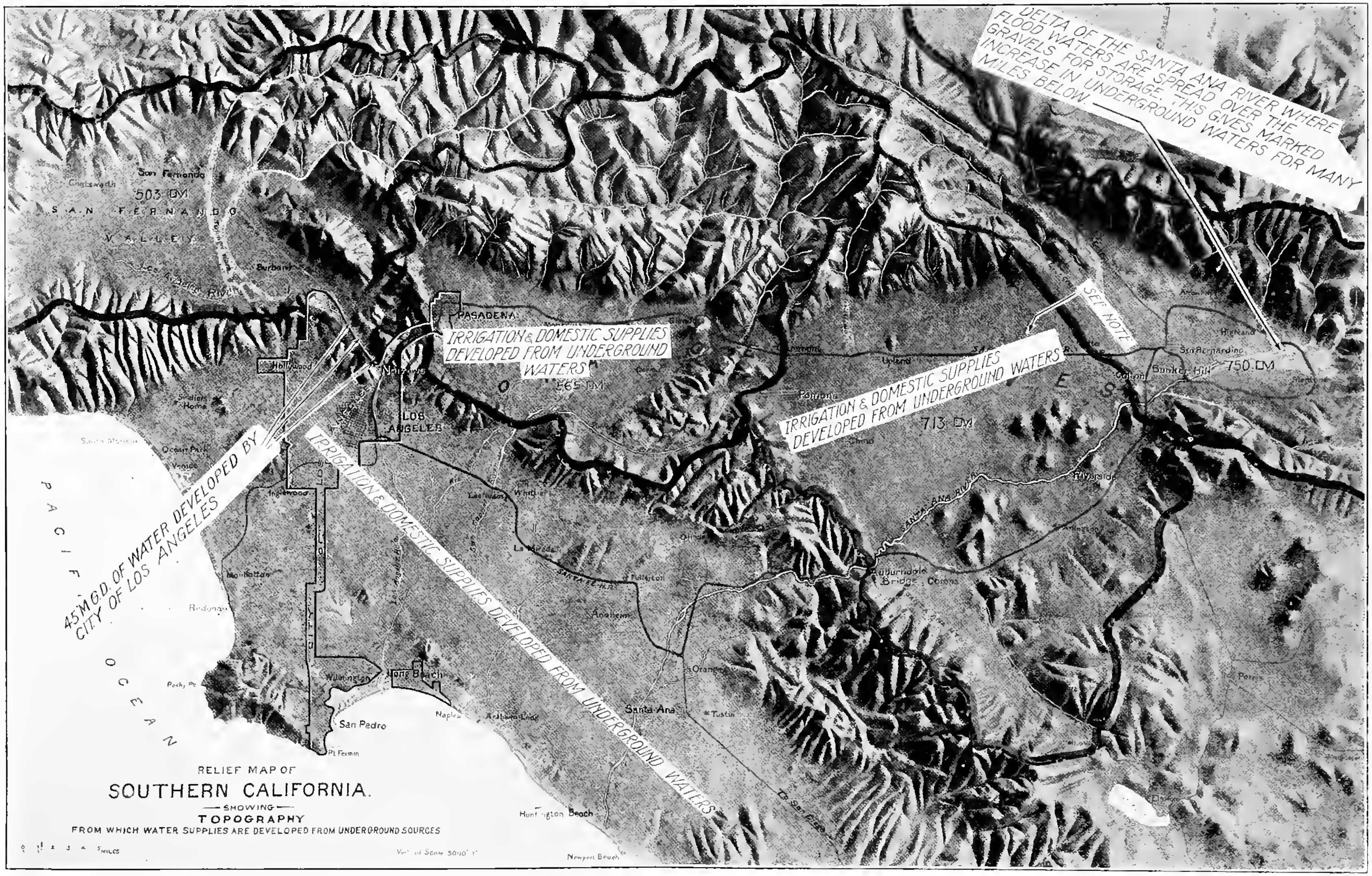
	Los Angeles River Drainage Area.	Livermore Valley Drainage Area.
High mountains..	174 sq. miles	202 sq. miles*
Foothills	153 " "	138 " "
Valley	176 " "	66 " "
Total	503 " "	406 " "

*Arroyo Valle above reservoir site and Mocho.

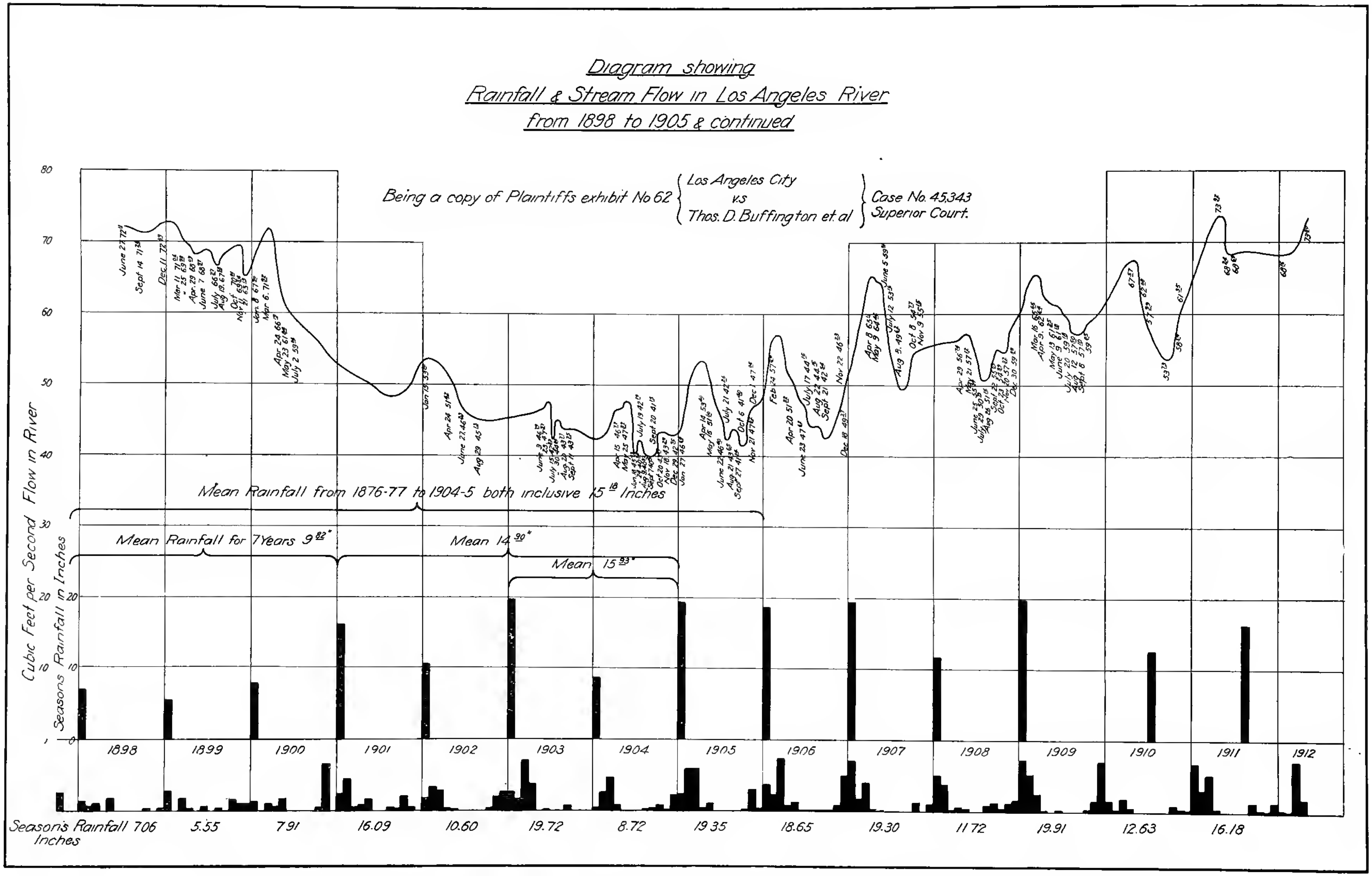
The rainfall generally in Southern California is less than that in the central portion of the State. The town of San Fernando in the San Fernando Valley had a mean precipitation in 25 years (1877-78 to 1901-02) of 13.98 inches. Its position in the San Fernando Valley corresponds to that of Livermore, which has a mean of 15.46 inches. The mean for Mt. Hamilton (31.5 inches) is, we believe, greater than that of the San Gabriel peaks on the Eastern crest of the Los Angeles River basin.

Underground Water Development of the San Fernando Valley.

San Fernando Valley has been filled with sand and gravel across its eastern end, and the floods of the Big and Little Tejunga branches are projected thereon, for a distance of 10 miles, and largely absorbed, to reappear at the Narrows, where the valley outlet is contracted. The foothills on the north, west and south of the San Fernando Valley are of shale and sandstone, which furnish a denser soil on the western two-thirds of the valley floor. The run-off from these foothills is carried well across these heavy lands, and in part, passes down through the Narrows in flood waves. In the Livermore Valley the greater portion of the water enters from the southeast corner and passes over the gravels east of Pleasanton for a distance of seven miles. These Livermore gravels are more interspaced with clay than those in the San Fernando Valley. There is a greater contraction of the outlet of the Livermore Valley than in the case of the San Fernando. The softer rock hills on



The development of underground waters is farther advanced here than in any part of United States.



Los Angeles River bears the same relation to San Fernando Valley that Laguna Creek does to Livermore Valley.

the east, north and west of Livermore Valley have their counterpart in the San Fernando, as described above, as also do the denser soils in the valley floor. The Livermore Valley has a so-called "clay cap" over 12 square miles near its outlet, producing artesian conditions which do not occur in the San Fernando, but resembling conditions above Colton in the San Bernardino Valley. This is an advantage to the Livermore Valley, as it improves the storage conditions. The water drains naturally from the San Fernando Valley, and forms the Los Angeles River by percolation, this outflow being uniform throughout the year except when sudden flood waves pass through. Laguna Creek does the same from Livermore Valley, but not so freely on account of the "clay cap" conditions. For this reason, the flood waves passing through the Livermore Narrows are probably relatively greater. If, however, the water is extensively drawn from the valley by means of wells, then the opportunities for storage will be increased correspondingly.

The flow of the Los Angeles River has been measured at the Narrows at Crystal Springs from June, 1898, to April, 1912. Exclusive of flood waves, the mean for that period of 14 years was 54 second feet. This does not include pumping by irrigators in the San Fernando Valley, which amounts to about 10 second feet, and the underflow escaping past the Crystal Springs, which will amount to five second feet more, a total of 69 second feet or 45 million gallons daily. During the midsummer months the inflow to the valley from the surrounding mountains is negligible. The estimated run-off for the Livermore Valley, based upon 36.4 per cent. of the Sunol measurements, and exclusive of evaporation losses, is 50 million gallons daily. Adding estimated evaporation losses in the Pleasanton bottoms, it is 62 million gallons daily. Based upon computations of rainfall and run-off made by us, we estimated the mean annual contribution to the Livermore Valley at 51.5 million gallons daily, which amount we accepted. As the mountainous portion of the basins above Laguna Creek and Livermore Valley is greater than in the case of the Los Angeles River, and as the rainfall in the former is fully as great, we believe it reasonable to expect as large a water crop therefrom as from the Los Angeles River.

Development of the Underground Water of the Drainage Basin of the Santa Ana River.

The Santa Ana River is an interesting example of the action of surface and return waters. This stream rises on the western slope of the San Bernardino Mountains. There is a total drainage area above Colton of 483 square miles of high mountains, and 267 square miles of foothills and valleys, making a total of 750 square miles in all. Above a point known as Rincon or the Auburndale bridge, on the same stream there is 555 square miles of mountains, 383 square miles of foothills and 525 square miles of valley, or a total of 1463 square miles. (See map in U. S. G. S. Water Supply Paper No. 59.) These latter areas are at a lower point on the same stream, and are referred to later in the discussion of the underground waters. The rainfall in the floor of the valley is from 10 to 15 inches, and in the mountains between 20 and 30 inches.

This district was investigated for the U. S. Geological Survey for two years prior to 1902, and Water Supply Papers No. 59 and 60, by J. B. Lippincott, were issued concerning it. The principal feature of this report is a discussion of the underground waters. During the summer season all of the streams entering the San Bernardino Valley are completely diverted for purposes of irrigation at the mouths of their mountain canyons. They are spread over the higher valley lands near the foothills first, and percolating towards the thalweg of the valley, they reappear as seepage or return waters. These percolating irrigation waters are augmented by the absorption of the winter floods in their porous delta cones. During the past two years the winter floods have been spread over the coarser gravels for the purpose of accelerating their absorption.

One and one-half miles northeast of Colton there is an outcropping of clay known as Bunker Hill. This region is the lower limit of the upper Santa Ana artesian belt. It also serves to force to the surface the return waters from irrigation that are percolating or flowing westward above a clay cap, which covers the lower portion of the valley, as in the case of the Livermore Valley. Six-sevenths of the water of Riverside is obtained from underground sources above this range of clay hills.

A somewhat similar condition is repeated at Rincon, where the Santa Ana River has cut its way through the lower Coast Range. At this point the underground waters are again forced to the surface and furnish the water supply for Anaheim, Santa Ana and Fullerton near the coast. Beyond these lower Narrows there is an open plain to the sea, and the Santa Ana River makes no further reappearance except in an artesian district below the 100-foot contour. This artesian and percolating water yields a very uniform flow. The development works near Colton and San Bernardino draw from this reservoir as a spigot draws from a tank. The flow is relatively uniform, and the tank is filled by winter floods and by seepage. The capping or uncapping of numerous wells in a neighborhood has little immediate effect on the flow of any well until the full discharge capacity of the underground conduit is approached. When that occurs, the water in all the wells is lowered and pumping must be resorted to.

The flat valley area above Colton comprises 132 square miles, and it is reasonable to estimate that 100 square miles of this consists of gravel deposits eroded from the mountains. These gravels are of unknown but great depths. Numerous wells have been put down to 900 feet and no bed rock has been encountered. In 1901 a record of 890 wells in this area was compiled. As the water plane is drawn down throughout this mass, its capacity to absorb subsequent floods at its rim, where the mountain streams debouch, is increased. It is a great regulating reservoir, sufficient in capacity to carry the irrigation communities through cycles of dry years, and to be recharged during those of copious rainfall. From data available in 1902, a withdrawal of 140 second feet of water, or 90 million gallons daily, was believed to be reasonably safe. In the same ratio per square mile of total drainage area, the Livermore Valley should yield 49 million gallons daily.

In September, 1900, there was being obtained above Colton from the valley floor 71 cubic feet per second of developed water, and 54 cubic feet per second of natural flow. On June 30, 1898, the Riverside Water Company alone was obtaining 69.40 second feet from this valley at the end of a period of five dry years. This was considered a normal summer flow from their various sources of supply. The Gage Canal which serves the Riverside District constantly diverts from one-half to two-thirds as much as the Riverside Canal, and all the waters of the Gage Canal are developed. These two canals serve the greatest orange-growing district in the State of California and probably the richest horticultural region in the world.

The following table indicated the return waters coming in above Rincon from the drainage basin of the Santa Ana River. The year 1898 was a dry year during a dry cycle:

	1898 June Sec. Ft.	1898 Sept. Sec. Ft.
Mountain streams above Colton	80	63
Mountain streams below Colton	21	17
Total summer streams from mountains	101	80
Return and developed water above Colton	138	145
Return water between Colton and Riverside Narrows	75	62
Return water between Riverside Narrows and Rincon	61	53
Total return water above Rincon	274	260

The discharge from the mountain streams, as previously stated, is all diverted. The seepage water that is flowing from the outlet of the valley is the return irrigation water and the regulated flood which has been absorbed by the gravels above. Of course, the outflow from the valley can be no larger than the inflow, when averaged through the different months of the year and through different terms of wet and dry years. The table is given as indicative of the very substantial nature of these underground waters. All these seepage return waters are completely used and are sustaining the population and horticulture of this district.

Development of the Underground Water of the San Gabriel River.

The same sort of a showing is made by the San Gabriel River. In July, 1898, a very dry year, the total flow of all the streams in the drainage basin of the San Gabriel River above the Narrows at El Monte, was 15.71 second feet, while the seepage and return waters at the Narrows was 62.85 second feet, and in August of the same year, the mountain streams were flowing 7.49 second feet and the return waters were flowing 52.6 second feet, or about 37 million gallons daily of seepage water. The San Gabriel

River drains about 319 square miles of the southern face of the Sierra Madre Mountains, and 246 square miles of valleys and foothills, about 20 miles easterly from Los Angeles. After leaving its mountain canyon, the flood waters pass over a great gravel cone, in which they largely disappear, and are again forced to the surface, together with return irigation waters, where the valley is contracted by the low foothills southeast of the city of Los Angeles.

Conclusions.

This discussion of the underground waters of Southern California could be materially extended. They exist in the Cajon Valley in San Diego County, in Ventura County and elsewhere. The reference to them is made here to show that on this coast we do not hesitate to build up great communities on water supplies of this character. In fact, we believe that underground water supplies stored in gravel beds of this character are the more reliable, freer from contamination, and usually are not subject to evaporation losses. Also they can be extracted in larger or smaller volumes, as circumstances require.

We believe the physical characteristics of the Livermore Valley closely resemble these conditions in Southern California.

We have been connected with the study of these underground waters and their development during the past twenty years or more, and in almost every instance, the amounts of water that have been obtained from these sources of supply have been greater than at first estimated.

Very truly yours,

WM. MULHOLLAND,

J. B. LIPPINCOTT.

REPORT ON THE PRODUCTIVITY OF LIVERMORE VALLEY, USING DATA FROM THE REPORT MADE BY CYRIL WILLIAMS, JR., ON ALAMEDA CREEK SYSTEM, TO JOHN R. FREEMAN

BY

WM. MULHOLLAND,
Chief Engineer of Los Angeles Aqueduct,

AND

J. B. LIPPINCOTT,
Assistant Chief Engineer of Los Angeles Aqueduct.

San Francisco, Cal., July 2nd, 1912.

S. P. Eastman, Esq.,
Vice-President and Manager Spring Valley Water Co., San Francisco, Cal.

Dear Sir:—

Supplemental to our report of February 2d, 1912, on the subject of the "Resources of the Spring Valley Water Company in the Livermore Valley," and responding to your inquiries prompted by that report, and other information and data on the subject now in your possession, we beg to respond to those inquiries in the order of their presentation:

Livermore Valley Filled With Porous Materials.

First, as to the structural geological features of the valley, as bearing on the probability of the valley fill being largely composed of impermeable clays. It is with diffidence that we approach this subject, for the reason that you have in your possession a geological report covering the region from a most eminent authority. There are certain features, however, that are obvious even to the layman with engineering training. The fact that there has been either a great down-throw of the land to the east of the Alameda ridge, or an up-lift of the Alameda ridge, or possibly a combination of both of those movements, along the fault line approximately following the east base of the ridge, is evident even to the unskilled observer. That the movement was a profound one is also evident, but it does not follow, and would be wholly inconsistent with all the observed occurrences of such movements, to reason that this great displacement occurred suddenly as a single cataclysm, or in increments of very decided displacements. Such faults occur, as far as can be observed, by slow degrees—inch by inch—and sometimes, though rarely, measurable by feet, and covering almost inconceivable periods of time. This being the case, it is impossible to imagine a condition at any time that would create a lake of any great depth in the Livermore Valley to the east of the fault line due to these movements, as the slowly relatively rising rim would be eroded down by natural processes about as fast as the displacements occurred, or, if not quite as fast, at least slowly enough to permit a filling of the depressed side of the valley floor with ordinary alluvial debris. The records of the wells about Pleasanton, however, are sufficient to discredit any such theory; the logs disclose soils, occasional clay beds and thick bedded gravels, with no evidence that the clay deposits were lacustrine in origin; in fact the formation differs in

no particular from the formations found in other valleys throughout the State, that resemble this in configuration and conditions of stream flow.

Value of Watershed as Integral Part of System Greater Than as a Unit.

Your second inquiry relates to the difference of appraisement as a water producing unit to be assigned to the watershed, when considered in its relation to the Spring Valley Water Company's Peninsula property, and attached thereto as against its consideration as an independent unit, as though it were the sole source, for instance, of supply of a city requiring approximately for its use, year by year, the total output of its watershed. It must be manifest that there can be but one answer to this question, and that is, that the drainage area is vastly more useful as an adjunct to the Spring Valley's peninsula supply, than it would be standing as an individual unit, for the reason that, in periods of low yield, the great impounded water sources of the Spring Valley Water Company can be relied upon to meet the deficiencies, and per contra, in the years of great yield, the excess production can be conveyed either directly to the great impounding basins on the Peninsula, the property of the Company, or delivered direct to the consumer, conserving for lean years the water already impounded in those basins. This, we believe, is the plan that has always been contemplated, and intended ultimately to be carried out in connection with this source of supply, so that it is unfair and unreasonable to confine any consideration of its value to the amount of water it may yield in the year, or series of years, of extreme drought, and unattached to the rest of the property of the Spring Valley Water Company.

Ultimate Water Yield of Livermore Valley.

Answering your third question as to the computed probable ultimate yield of the watershed, as given in the original report, it may be said that the quantity there given amounts to about .155 second feet per square mile of the area of the shed, including the valley floor, and in fact, all the area, both mountain and valley, embraced in the subdivisions shown on the map tributary to Laguna Creek. This quantity expressed in depth in inches, over the catchment area, or over the whole basin, is 2.1 inches, and is somewhat less in amount than that obtained from the San Fernando Valley, which supplies the City of Los Angeles with water at the present time, which has a somewhat less rainfall on the average, and is more subject to intermittent and protracted visitations of drought than is the Livermore Valley, there being a record of recent date of a period of seven years grouped in succession in which the aggregate rainfall was but 60 per cent of the normal. Indeed we have no hesitation in asserting that, by having proper recourse during years of drought to the Livermore Valley gravels, the estimate given, viz.: 35 to 40 million gallons per day, was very conservative.

It has been called to our attention that, for some reason altogether unexplained, no value is attached to the 140 or 150 square miles of territory lying to the north and west of the Livermore Valley, comprising the Alamo, Tassejero, and Positas Creek watersheds. This is alleged to have been done for the reason that the soil is said to be tight and unabsorbent, also that the precipitation is small on these watersheds.

On the latter point the rain gages in the vicinity of Dublin, and westerly therefrom, which are the ones most adjacent and applicable to those regions, indicate precipitation which is rather greater than the average, and from the peculiar mountain conditions of the country it may, almost with certainty, be expected that along the Diablo range to the north, the precipitation is at least equal to the average of that of the whole shed, for the reason that the saturated winds from the ocean come without interception, or with comparatively little interception, to rob them of their water burden, across the gap in the coast created by San Francisco Bay, and reach the elevated country in this range on which to precipitate their first contribution in the way of rainfall in their easterly trend across the continent.

Porosity of Valley Fill.

As to the second point, that of tightness of the soil: We cannot see where there can be any material difference in the porosity of the soils or rocks composing this mountain

region, from that of the valley of Arroyo del Valle, for instance. The fact that the streams do not debouch on great superficially visible gravel fans, as do the streams of the Arroyo del Valle, and Mocho, does not mean that the waters are not in large measure absorbed and slowly released into the gravels of the valley floor that lap the flanks of the mountain beneath the present soil surface.

A very cursory examination of the country lying to the east and north of Dublin will show that nearly the whole flat area is in a state of saturation, and, as pointed out in the report already rendered, is probably underlaid with gravel deposits that reach up to the rock rim.

To assign no value to this great area would be tantamount to declaring that different materials used in roofing a building will shed more or less rain than other materials. In short, we have no hesitation in emphatically declaring that developed wells along the west and north edge of the valley floor will produce quite as abundantly as wells in any other portion of the valley, and that the water derived will have its origin in this area which has been so cavalierly disregarded.

As stated in the former report, there is nothing to indicate that these so-called clays are anything more than land formed soils of somewhat clayey composition. The valley of what is known as San Jose Creek, the mouth of which lies about 20 miles east of the City of Los Angeles, the valley itself being about 12 miles long, and draining an area of about 40 square miles, the formation of which is almost wholly of tight appearing sedimentary rocks, such as sandstone and shales, yields as much water per square mile as the San Fernando Valley, although the rainfall in it is somewhat less, and its mountain area much lower in elevation and slope. The deposits of debris in the thread of the valley are, moreover, very narrow, shallow and restricted in volume, notwithstanding which its water yield sustains many thousands of acres of highly productive orchards and alfalfa farms.

The seepage into these gravels is laterally from the sides of the valley, and is, with the exception of a very few places, subsurface and invisible, and we would expect the same condition to exist with reference to the Alamo, Tassajero and Positas drainage systems, and we feel free to assert that there is strong local evidence that this condition does exist.

The Livermore Valley floor itself, with the relatively copious rainfall of this region, can be relied upon to contribute no small share to the maintenance of the water supply in the gravels that underdrain it. Ground water, sustaining perennial river flows in flat countries in other portions of the United States, can be cited in support of this assertion, and illustrates that mountain catchment areas are not prerequisite to the existence of abundant ground water, neither as to quantity nor constancy of yield.

Livermore Valley a Vast Underground Reservoir.

The fourth question, which is to the effect that, assuming the existence of a record that only showed a water crop for two years in succession of about 14 million gallons per day, to what extent the gravels of the valley, when fully developed by intelligent grouping and placing of wells, with pumping equipment, could be relied on to supplement the supply, we will say that computation, based on the disclosures derived from the well logs of the formation existing in the valley floor, leads to the conclusion that the voiding of the top 40 feet of the water plane provides sufficient volume to yield about 20 M. G. D. for 2 years, and the feat of mechanically raising it can be accomplished without doing violence in any way to practicability, and is being commonly done in many regions in Southern California at present, and for many years past.

Partial Review of the Report of Cyril Williams, Jr., Relative to a Water Supply From the Livermore Valley.

There are three salient points to be considered relative to obtaining a permanent water supply from the Livermore Valley:

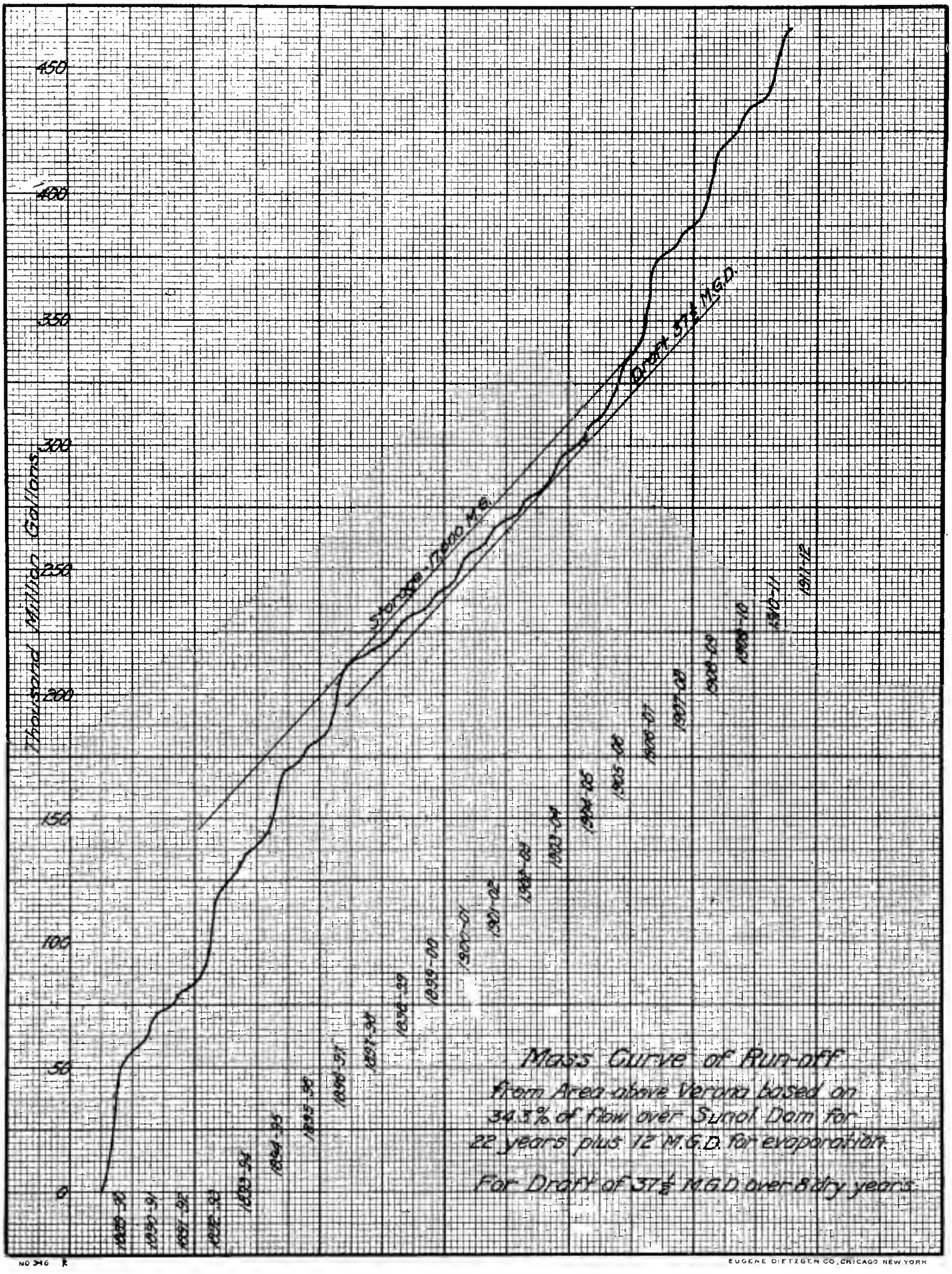
1st. What is the annual water crop, or run-off, projected on to the gravels?

2nd. What may be considered as the reasonable inflow into the gravels?

3d. What amount may be extracted from the gravels?

Run-off.

The discussion of the rainfall and run-off along theoretical lines is relatively unimportant, in



Thousand Million Gallons
450
400
350
300
250
200
150
100
50
0
Storage 17,000 M.G.
Draft 37½ M.G.D.
1889-90
1890-91
1891-92
1892-93
1893-94
1894-95
1895-96
1896-97
1897-98
1898-99
1899-00
1900-01
1901-02
1902-03
1903-04
1904-05
1905-06
1906-07
1907-08
1908-09
1909-10
1910-11
1911-12
Mass Curve of Run-off
from Area above Verona based on
34.3% of flow over Sunol Dam for
22 years plus 12 M.G.D. for evaporation.
For Draft of 37½ M.G.D. over 8 dry years.
NO 346 R
EUGENE DIETZGEN CO. CHICAGO NEW YORK

view of the measured records of Alameda Creek at the Sunol dam. We agree with Mr. Williams, that the most reliable run-off data are actual stream measurements in the basin, and we will accept with him the Sunol gagings. (Pages 148 and 160.*)

The only purpose of a theoretical study of run-off data of Alameda Creek is to permit the distribution of the amounts measured at the Sunol dam to the various portions of the basin. Four independent distributions of this measured Sunol flow have been made for Livermore Valley:

Mr. Schussler's from personal observation....	36.4%
Mr. Williams' report, see table page 203......	34.3%
Mulholland and Lippincott	44.0%
Mr. Hermann	43. %

Mr. Williams' ratio of 34.3% is accepted here, and a mass curve has been made, founded on this per cent.

There is no valid reason that we see for eliminating the first year of observation (1888-9) at Sunol. The Sunol mean flow, by this process, is lowered from 138 to 120 m. g. d. (Page 157 Williams' report.) This, however, does not affect results for the critical period.

MASS TABLE BASED ON 34.3% OF MEASURED FLOW AT SUNOL DAM AND 12 M. G. D. EVAPORATION LOSS FROM WET LAND.

Season	M. G. at Sunol	34.3% from Pleasanton	M. G. evapor. + 4380 per year	M. G. total for Pleasanton
1889-90	153,634	52,600	56,980	56,980
1890-91	36,590	12,520	16,900	73,880
1891-92	19,348	6,630	11,010	84,890
1892-93	102,039	34,950	39,330	124,220
1893-94	55,638	19,080	13,460	137,680
1894-95	81,565	27,980	32,360	170,040
1895-96	37,231	12,770	17,150	187,190
1896-97	63,825	21,850	26,230	213,420
1897-98	3,732	1,280	5,660	219,080
1898-99	24,623	8,440	12,820	231,900
1899-00	17,960	6,150	10,530	242,430
1900-01	31,828	10,920	15,300	257,730
1901-02	19,793	6,780	11,160	268,890
1902-03	23,199	7,950	12,330	281,220
1903-04	37,771	12,920	17,300	298,520
1904-05	20,254	7,000	11,380	309,900
1905-06	63,134	21,810	26,190	336,090
1906-07	102,917	35,200	39,580	375,670
1907-08	21,189	7,250	11,630	387,300
1908-09	83,989	28,750	33,130	420,430
1909-10	33,949	11,610	15,990	436,420
1910-11	74,852	25,610	29,990	466,410

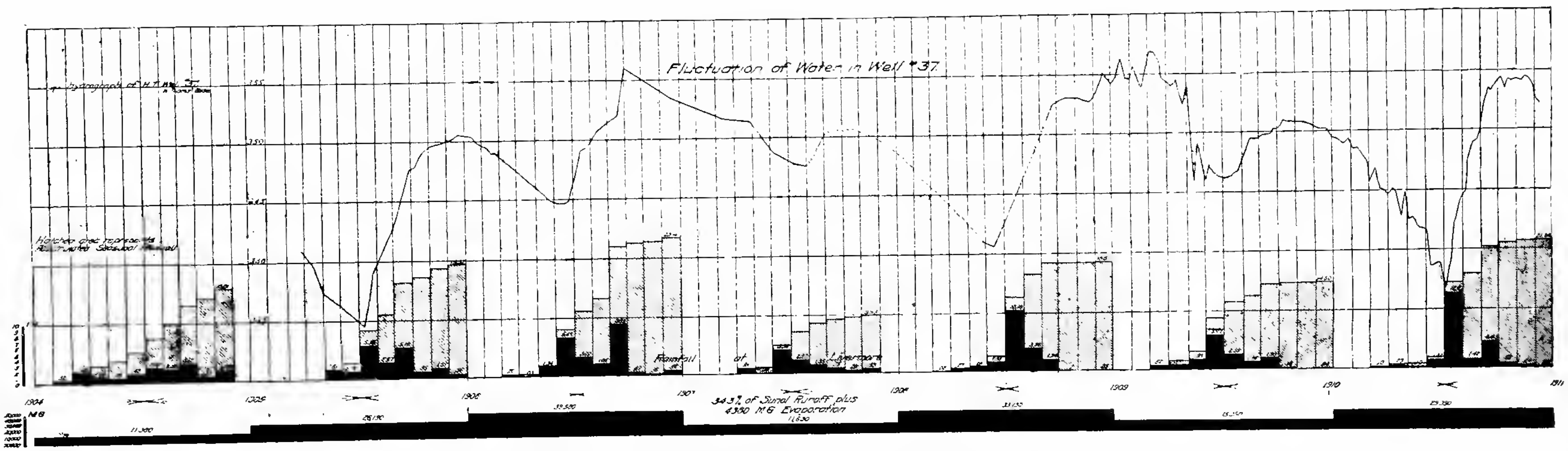
Estimated 22 yr. mean flow over Sunol dam from Pleasanton................	46.1	M. G. D.
Estimated evaporation from Pleasanton region	12.0	"
Total evaporation and stream flow..	58.1	"

*The page references herein made relate to the Cyril Williams, Jr., report on Alameda Creek system filed August 1, 1912, in San Francisco, Cal., with the Advisory Board of Army Engineers, a copy of which report when originally prepared early in 1912 was furnished the Spring Valley Water Company.

Note an evaporation of 12 m. g. d. is here used, though we believe that this annual loss is higher (17.311 m. g. d.), because in handling this storage reservoir in the gravels it may not be possible to prevent all this loss.

A mass curve is made from the above table, based on a withdrawal of 37.5 m. g. d., as given in our report of February 2nd, 1912, as the available supply without surface reservoirs. The controlling period is from 1897-8 to 1905-6, or 8 dry years. This shows a storage necessary to meet this drought of 17,000 m. g. We take 12.1% of the total volume, as the yield from the gravel reservoir, as determined from the fall of the water plane during the 100-day period, as described below, 17,000 m. g., divided by 0.121 voids, gives 140,-500 m. g. as the volume of gravels to be drained to meet the conditions of the mass curve, of 431,335 a. f. over 24 square miles, the estimated total area of the gravel reservoir. This would call for a depth of 28 feet. To this 28 feet should be added the 8 feet necessary to hold the water below the influence of the surface evaporation, or 36 feet in all of storage to secure the flow of 37½ m. g. d. These figures are modified from those of our report of February 2nd, 1912, in an endeavor to accept Mr. Williams data, so far as it seems tenable.

The discharge from the north side of the valley, or other floods, may be put over the Sunol gravels, and these may be more vigorously attacked, as contemplated in our former report. It is also possible to put Positos and Cottonwood waters on the gravels of the Arroyo Valle on the south side of the valley. It is not just to consider all of this water wasted, as Mr. Williams does on page 188. In our judgment there is no continuous clay cap over the Pleasanton region. Mr. Williams states that it has "springs and holes" through it, and the water comes up through it (pages 254 and 260). If the water will come up through the "clay cap," when drained below it would admit surface water downward. In our opinion there is no justification for concluding that there is an impervious barrier between the north and south sides of the valley northwest of Pleasanton. Our observations here, and elsewhere, are that the clay and gravel are laid down in irregular masses, or lenses, that are not continuous. See logs, pages 286 and 287, of closely adjacent wells. We con-



HYDROGRAPH OF WELL IN LIVERMORE VALLEY.

This is the well which Mr. Williams states is typical and that its fluctuations may be taken as a gage to the volumes in the gravel reservoir.

sider the Geological Sections given by Mr. Williams, on line N. & S. 4, page 278, and E. and W. 7, page 272, show the gravels as practically coming to the surface at well 30-A. Geological Section N. & S. 3, page 277, indicates that there really is no dyke across this valley between wells 93 and 63. Also see "F" line of wells, page 285, and "H" line, page 287, which show sand at surface in places. Alkaline waters, crowding in from the north, would show their characteristic, whether they were in motion or not. Their different mineral contents may show a separate origin, but not a different destiny. (Pages 365 and 366.)

Inflow Into the Gravels.

Mr. Williams has extensively discussed the capacity of a certain prism drained during a 100-day period, the volume of which is computed from the observation on the fall in a large number of wells distributed throughout the Livermore Valley. We have checked and accepted the volume of this prism of 22,000 m. g., but have modified the amount of water that he estimates as withdrawn from it during the 100-day period, from 6% to 12.1%, for reasons stated in the discussion of "Outflow," below. Branner's well No. 96 (Williams' No. 103 and Tibbetts' No. 37) is 3300 feet north of the S. P. R'y, and 7500 feet east of the Santa Rita road, and fairly within the gravel reservoir of the valley. Mr. Williams states that this is a typical well, and that its fluctuations may be taken as a gage to the volumes in the gravel reservoir. He stated (page 350) "the fall of 4 feet in 100 days in well No. 103 represents a loss in storage available at Pleasanton of 1270 m. g." For reasons given below, we increase this output to 2659 m. g. for this prism, or 664 m. g. per foot of fall in the well. If the fall of 1 foot represents a loss of 664 m. g., a rise of 1 foot would represent a gain of an equal amount. Fortunately we have a record of this well, covering a period of five years, one of which appears, however, to be defective. A hydrograph is attached showing this record. From this record the computed inflow into the gravel is shown in the following table:

INFLOW INTO THE LIVERMORE GRAVELS, AS INDICATED BY THE RISE IN WILLIAMS' WELL NO. 103 (BRANNER NO. 96 AND TIBBETTS' NO. 37) BASED ON THE VOLUME OF WILLIAMS' 100-DAY PRISM, BUT WITH 12.1% VOID DRAINABLE.

Season	Rise in feet.	Indicated inflow M. G.	Period of Rise days	Est. rate outflow during period of rise M. G. D.	Total est. outflow during period of rise M. G.	Total outflow and inflow in M. G.
1905-6	15.8	10,491.2	163	26.593	4334.8	14,826.0
*1906-7	11.5	7,536	111	26.593	2951.9	10,487.9
1907-8	No record					
1908-9	16.2	10,756.8	243	26.593	6462.3	17,219.1
1909-10	5.3	3,519.2	150	26,593	3988.9	7,508.1
1910-11	18.1	12,018.4	135	26.593	3590.1	15,608.5

Equivalent inflow M.G.D.	Est. total Seasons runoff M. G. D.	% flow sinking into gravels
40.6	71.9	56.5
28.7	108.4	26.5
47.1	90.7	52.
20.6	43.8	47.
42.7	82.1	52.

We, therefore, have the following ratios of run-off, as measured at Sunol, to inflows as indicated by this computation, eliminating the season of 1906-7, which we believe to be a defective record:

1905-6	56.6	per cent.
1908-9	52.0	" "
1909-10	47.	" "
1910-11	52.	" "
Mean	52.	" "

As more water cannot enter gravels that are already saturated, we consider that a higher per cent would have entered into the gravel reservoir if it had been depleted by more extensive pumping prior to these flood discharges, and if the waters had been artificially spread over larger areas than the natural storm channel of the creeks. Also the effect of the run-off of the N. W. portion of the basin would have little effect on this well. (Williams No. 103.) With one exception (1909-10) these were years of high run-off, and that one exception was estimated as a (43.8—58.1) 75% year. If we assume that the above 52% inflow may, by spreading and more extensive withdrawals, be increased to

*Note: The small amount of water sinking into the gravels during the season of 1906-07 is readily understood when it is known that the reservoir was already full. This is shown by Williams' hydrograph on page 353b and by Tibbetts' hydrograph. The condition of high water table of that season is also shown by other wells near by. Williams' well No. 77, situated a short distance to the north of 103, began flowing on April 1st of 1907 and continued until July.

65%, and taking the mean product of the basin as given on the mass table as 58.1 m. g. d., we have as a possible inflow capacity of 37.8 m. g. d., which is as much as the amount estimated upon in our report of February 2nd, 1912.

During the dry year of 1911-12 all of the water of the Valle and Mocho sank into the gravel reservoir.

MEASUREMENTS OF INFLOW BY T. W. ESPY FOR THE S. V. W. CO. ON THE ARROYO VALLE CREEK DURING 1912.

Date 1912	Upper Measure s. f.	Lower Measure	Length of Channel	First point of meas. on Arroyo Valle at Clay Bridge
Jan. 27	45.5	0	4,770′	....
Mar. 13, 9 a. m.	142.5	0	13,800′	....
Mar. 13, 5 p. m.	117.6	0	13,800′	....
Mar. 14, m. ...	87.8	0	14,800′	....
Mar. 15	64.	0	14,800′	....
Mar. 16, 6 a. m.	83.	0	14,800′	....
Mar. 16, 6 p. m.	72.	0	14,800′	....
Mar. 17	44.	0	14,800′	....
Mar. 18	35.	0	12,550′	....

ON THE MOCHO.

Date 1912	Upper Measure s. f.	Lower Measure	Length of Channel	First point of measure Still bridge
Jan. 26, 5 p. m.	7.5	0.4	4,320′	....
Jan. 26, 9 p. m.	11.4	0.	4.320′	....
Jan. 27, 9 p. m.	7.5	0.	4,320′	....
Mar. 12, 7 p. m.	49.0	0.	4,320′	....
Mar. 12, 10 p. m.	59.	0.	4,320′	....
Mar. 13, 2 a. m.	43.	0.	4,320′	....
Mar. 13, 6 a. m.	27.	0.	4,320′	....
Mar. 13, 12 m..	19.3	0.	11,200′	....
Mar. 13, 8 p. m.	14.5	0.	11,200′	....
Mar. 14, 7 a. m.	11.4	0.	11,200′	....

During the rains the waters of the Tassajero Creek discharged into drainage ditches, and ran through them to Laguna Creek. All of the Valle and Mocho water sank into the gravels. It has been suggested that the muddy storm waters projected for a long period onto the gravel cones would seal them with silt, so that they would become impervious. This, in practice, does not occur. On Jan. 27, 1912, we personally saw 45 s. f. (29 m. g.) sinking in 3000 feet of the channel gravels of the Arroyo Valle. We know, from the continued effective use of the Sunol gravels, and the fluctuations of the wells in Livermore Valley, that water does freely enter the gravels. While silt is deposited in the streams by absorption into the gravels, the next high flood, by rolling and shifting the gravels, scours them, and washes the silt on to lower levels.

Outflow from the Gravels.

Study of the withdrawal during the 100-day period, from Williams prism, Oct. 1, 1911, to Jan. 9, 1912:

Mr. Williams states that the outflow from this prism during the 100-day period was (page 349) 12.709

His only measurement, made on Laguna Creek at Sunol during this period, was 5,508,000 g. p. d. on Nov. 17, 1911 (page 348). This was in the middle of this period. Some rains fell during the 100-day period that confuses the condition, but the prevailing flow of the Laguna Creek was greater, rather than less, than the above amount, as indicated by a hydrograph of the S. V. W. Co. He accepts a lower measurement, made Feb. 9, 1912, 31 days after the 100-day period, of 4,500,000 g. p. d. (page 348). From his measurements, and those of the S. V. W. Co., we believe there was a mean flow in Laguna Creek of at least 5,508,000 g. p. d. Therefore, we add to Mr. Williams' estimate of outflow...... 1.008

We see no reason for making any deduction for the flow of the Positas, on the theory that this water does not enter the gravels (page 348). Attention is called to this note on profile of water plans, page 424, which shows one point where the gravels drain into the the Positas.

13.717

Mr. Williams states that water comes up through the "clay cap" in springs, and is drained off by canals (page 229). If it will come up, it will also go down when the underground reservoir is drained. Mr. Williams states (page 231): "A secondary loss is that which occurs as the result of the evaporation of waters forced upward locally through lines of weakness in the 'clay cap'." We believe there are numerous openings of this nature, and of substantial area. In June, 1912, at the end of a dry winter, and after the construction of drainage ditches, and the operation continuously of the pumps of the S. V. W. Co., there is an area of 255 acres N. W. of Pleasanton which is saturated to the surface.

While Mr. Williams refers to the evaporation losses from the Valley floor (page 231), he makes no allowance for them in

his estimated outflow from the valley. In our report of February 2, 1912, from observations of the water plane at that time, we state this evaporation loss was 12.028 m. g. d., using round figures, 12.0 m. g. d., which was lower than actual computation.

The actual computation shows (1.83′ × 640a × 12 mi. ÷ 3.07 × 365 days, 12.544 m. g. d.).

Our statement at that time, therefore, was too low by .516 m. g. d.

	m.g.d.	m.g.d.
	12.544	13.717
From data that has been obtained since the writing of our report (Feb. 2nd, 1912) on the evaporation from soils in Owens Valley, owing to the developments of plant and root growth in the soil in the pans, we find that the figures then used were too low by 15%, which should here be added. This will probably increase further..........	1.882	
This gives	14.426	
We used, on Feb. 2nd, 1912, an evaporation as a basis of comparison from a water surface in Livermore Valley of 40″ Mr. Williams states (page 439) that the evaporation losses in this region are 48″ per annum, or 20% greater than we used. Therefore this 20% should be added: 14.426 × .20 equals...	2.885	
Therefore the total annual evaporation loss from the 12 square miles should be.........	17.311	
From the Owens Valley records we find the ratio of evaporation for this period from Oct. 1 to Jan. 9 is 72% of the mean annual rate, so that 72% of 17.311 m. g. d. should be added to the surface stream flow from the valley during the 100-day period.		12.464
		26,181

On page 231 Mr. Williams states that water is escaping down the Sunol Canyon, and shows an inflow to the Laguna Creek, by seepage above the Sunol Bridge, of 823,000 gal. in 2½ mi. of the canyon, or at the rate of .33 m. g. d. per mile of canyon. On page 558, on Nov. 17, 1911, he finds 18.648 m. g. d. at the Sunol Dam, of which 17.649 m. g. d. can be accounted for from measured sources, leaving 1.000 m. g. d. to be accounted for by seepage from the Sunol gravels or from seepage into Laguna Creek. The distance along the creek from the bridge to the dam is 1¼ mi. If the rate of increase, due to underflow into Laguna Creek continues for this 1¼ mi. we have .33 m. g. × 1.25 .412

26,593

This quantity is indefinite, but there is no reason to believe that this increase stops at the last point of measurement on Laguna Creek at the Sunol Bridge with a bed rock dam 1¼ mi. below and a large bed of gravel intervening. We, therefore, have a total estimated outflow from the entire Pleasanton region of 26.593 m. g. d., as compared to Mr. Williams' 12.709, or an increase of 109%.

Mr. Williams finds that the voids drained in his prism amount to about 6% when he used an outflow of 12.709 m. g. d. By using our revised outflow figures of 26.593 m. g. d. for the 100-day period, this is increased to (2659.3 m. g. ÷ 22,000 m. g.) 12.1%. This 12.1% we consider too low, but it is used in this argument.

Mr. Williams states that 40% of the valley fill is gravel, and that but 15% of this gravel is available storage, thus obtaining the 6%. This 6% we consider obviously too low a figure, and it does not accord with his determination of voids given on page 378. It is our opinion that the voids in sands and gravel are 35%, and we have used 35% in our report which agrees with the per cent of voids determined by Mr. Espy, and given in the table attached.

Accepting the volume of the Williams prism

as 22,000 m. g. (page 349) the volume of water withdrawn as (26.593 m. g. d. × 100 days) 2659.3 m. g., we have 12.1% of the mass drained. This is 71% of the figure which we would apply from our report of Feb. 2d, 1912. It is probable that the denser material is not as freely drained as the gravels, and probably these denser materials have not fully yielded their water during the 100-day period. Also some of the wells used to show the 100-day drop in the prism we believe to be affected by local pumping: e.g. his No. 185.

For the sake of the discussion we will accept 12.1% of the gravel reservoir as voidable, though we believe it too low. This is the per cent of water estimated to have been drawn from the prism as defined by Mr. Williams in the 100-day interval.

Mr. Espy, for the Spring Valley Water Company, made a determination of voids in the various soils of the Livermore Valley, as given in the following table. This was done by pouring the soil into the water and then shaking, instead of trying to pour water into the soil.

Voids in the Soils of Livermore Valley.

Class of soil	Sample taken near contact with:	Sample No.	% Voids		Av. %
Mocho	Mg	9	34.0	30.0	
gravelly	Mg	39	38.7	35.5	
sandy	Liverm. Loam	3	46.1	35.9	
loam	Lg	27	26.4	26.4	34.1
			273.0		
Mocho			54.0		
silty fine	Ll	15	45.0		
sandy loam					
			99.0		49.5
Livermore		4	27.5	25.9	
gravelly	Lg	10	15.5	15.2	
sandy loam		11	18.7	18.1	
		31	23.3	22.5	
		32	27.6	27.9	
		36	24.2	25.8	
		43	27.5	26.6	
		44	30.4	31.7	
		45	29.6	27.9	
		47	30.6	27.2	
		48	31.0	29.5	
	Lf	5	44.4	46.7	
	Pl	2	29.6	24.0	
	Pl	6	28.4	27.3	
			764.6		27.3
Livermore	Lf	40	37.9	34.2	
fine	Ll	41	38.7	37.9	
sandy loam					
			148.7		37.2
Livermore			38.7		
silty fine	Lf	13	45.0		
sandy loam					
			83.7		41.6
Livermore	Lg	42	41.2	40.0	
loam	Ll	28	30.9	32.6	
		29	32.3	32.8	
		30	29.3	30.2	
		38	42.6	40.0	
			351.9		35.2
Pleasanton	Pl	1	36.8		
loam		7	36.7		
		8	33.0	34.3	
		33	29.2		
			170.0		34.0
Santa Rita	Sl	14	44.6	49.1	
loam		37	37.0	35.4	
			166.1		41.5
Livermore	Ll	35	34.6	47.9	
clay	Ll	46	33.6	30.8	
			146.9		36.7
Ulmar		34	36.4	43.3	
loam					
			79.7		38.8

See also Williams' determination of voids, page 378.

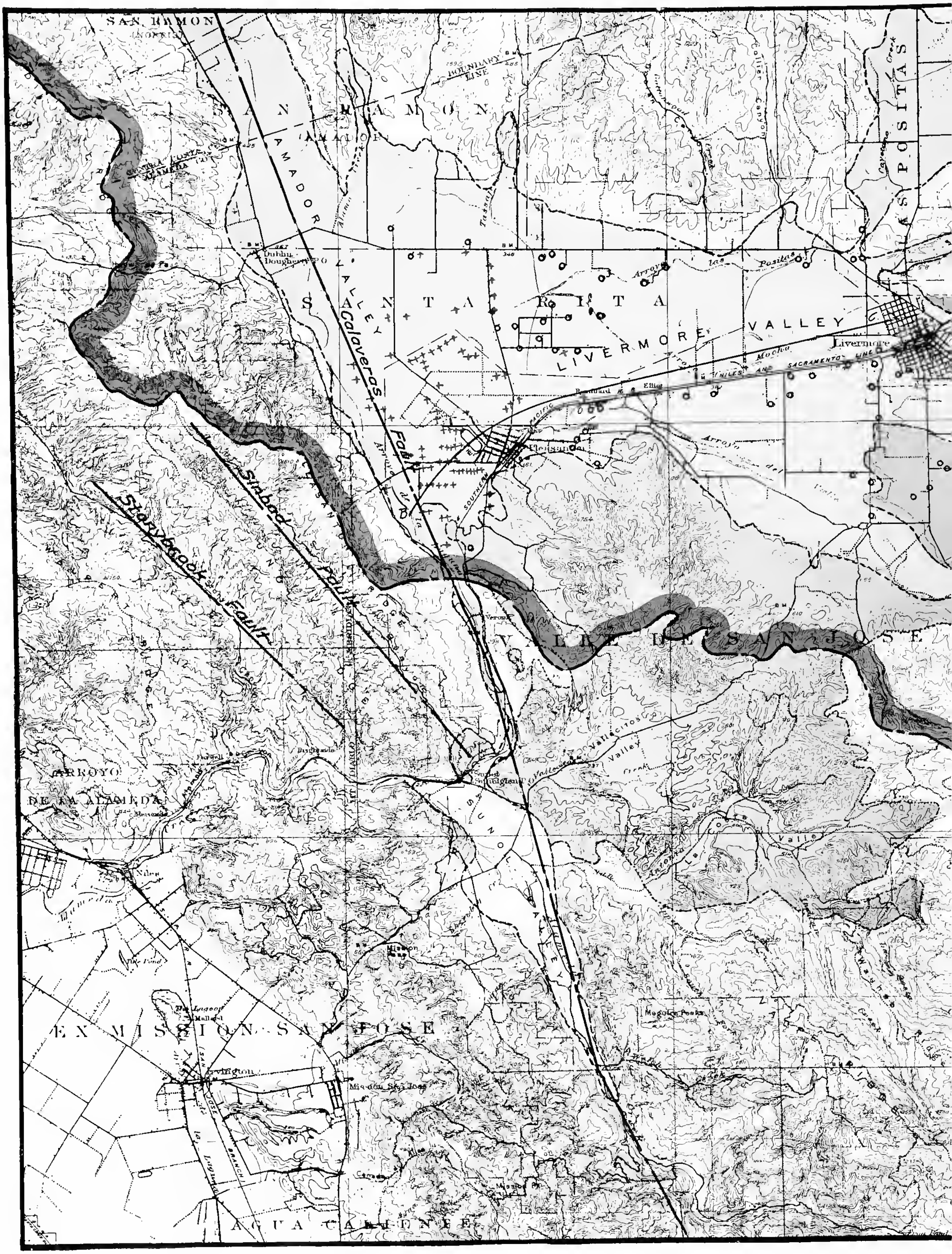
Conclusions.

From the further consideration of the available water supply of the Livermore gravels, and the study of the additional data furnished us by you, we see no reason for the modification of our report of Feb. 2nd, 1912, which was that "without the construction of the Arroyo Valle reservoir, from 35 to 40 m. g. d. continuous flow can be developed from the gravel beds of Livermore Valley. With the Arroyo Valle Reservoir this amount may be made to closely approximate the full mean annual water crop of the drainage basin, estimated at 51.5 m. g. d."

Very respectfully,

WM. MULHOLLAND.

J. B. LIPPINCOTT.


SAN RAMON
BOUNDARY LINE
S A N R A M O N
AMADOR
AMADOR VALLEY
Dublin
S A N T A R I T A
Calaveras Fault
Arroyo las Positas
LAS POSITAS
LIVERMORE VALLEY
Livermore
Mocho
NILES AND SACRAMENTO LINE
PACIFIC
SOUTHERN
Pleasanton
Arroyo del Valle
Sinbad Fault
Stonybrook Fault
Verona
V A L L E D E S A N J O S E
Vallecitos
Valley
Creek
Sunol
ARROYO
DE LA ALAMEDA
SUNOL
Niles
Mission
EX MISSION SAN JOSE
Irvington
Mission San Jose
Mallard
Tule Pond
Mission Peaks
AGUA CALIENTE

MAP
Showing the distribution of the Pliocene gravels & sands South of the Livermore Valley
by J C.Branner.
Location of Wells.
Recent Valley deposits. 58 DM.
Pliocene Gravels. 47 DM.
Miles
Kilometers
Contour interval 25 feet
Datum is mean sea level.
LIVERMORE
Arroyo
LAS POSITAS
Las Positas
VALLEY
CRANE
RIDGE
Hollow
Corral
Hollow
Mendenhall Springs
CEDAR
MOUNTAIN
RIDGE
Cedar Mtn
Sugarloaf Butte
Mud Springs
Lookout Pt.
Williams
Gulch
Canyon
Callahan
Gulch

REPORT OF THE GEOLOGY OF LIVERMORE VALLEY

BY

Dr. J. C. Branner,

Vice-President of Stanford University and in charge of the Department of Geology.

Stanford University, Calif.
December 1, 1911.

Spring Valley Water Company, San Francisco, Calif.

Gentlemen:

I beg to submit the following report upon the underground water conditions of the Livermore Valley.

Work Done.

A few years ago I had my assistants work out the general geology of the entire area covered by the Pleasanton and Tesla sheets of the U. S. Geological Survey, in which the Livermore Valley lies.

During the past two and a half months I have had two assistants at work on the Livermore Valley and the surrounding region, and I have myself also gone over the valley and the geology around its margins.

I have received from the office of the Spring Valley Water Company 157 records or logs of wells about Pleasanton and within the Livermore Valley.

Other logs to the number of 54 have been collected by Mr. Hook, under my direction, along the northern margin of the valley, and in the vicinity of Livermore.

The general geology of the region surrounding the valley has also been worked out, not only on the Pleasanton sheet, but on the topographic sheets east and south of it. Upon the data thus collected the conclusions given below are based.

The Wells in the Valley.

The total area of the flat-floored part of the Livermore Valley is about 58 square miles. Within this area, but very irregularly scattered over it, I have the logs of 211 wells. These wells average 82.7 feet in depth. The deepest ones in the filled-in materials are in the town of Livermore (212′); another near the race track west of Pleasanton has a depth of 214 feet. The deepest of all is just south of Pleasanton and has a depth of 275 feet, but this is probably mostly in the older gravels.

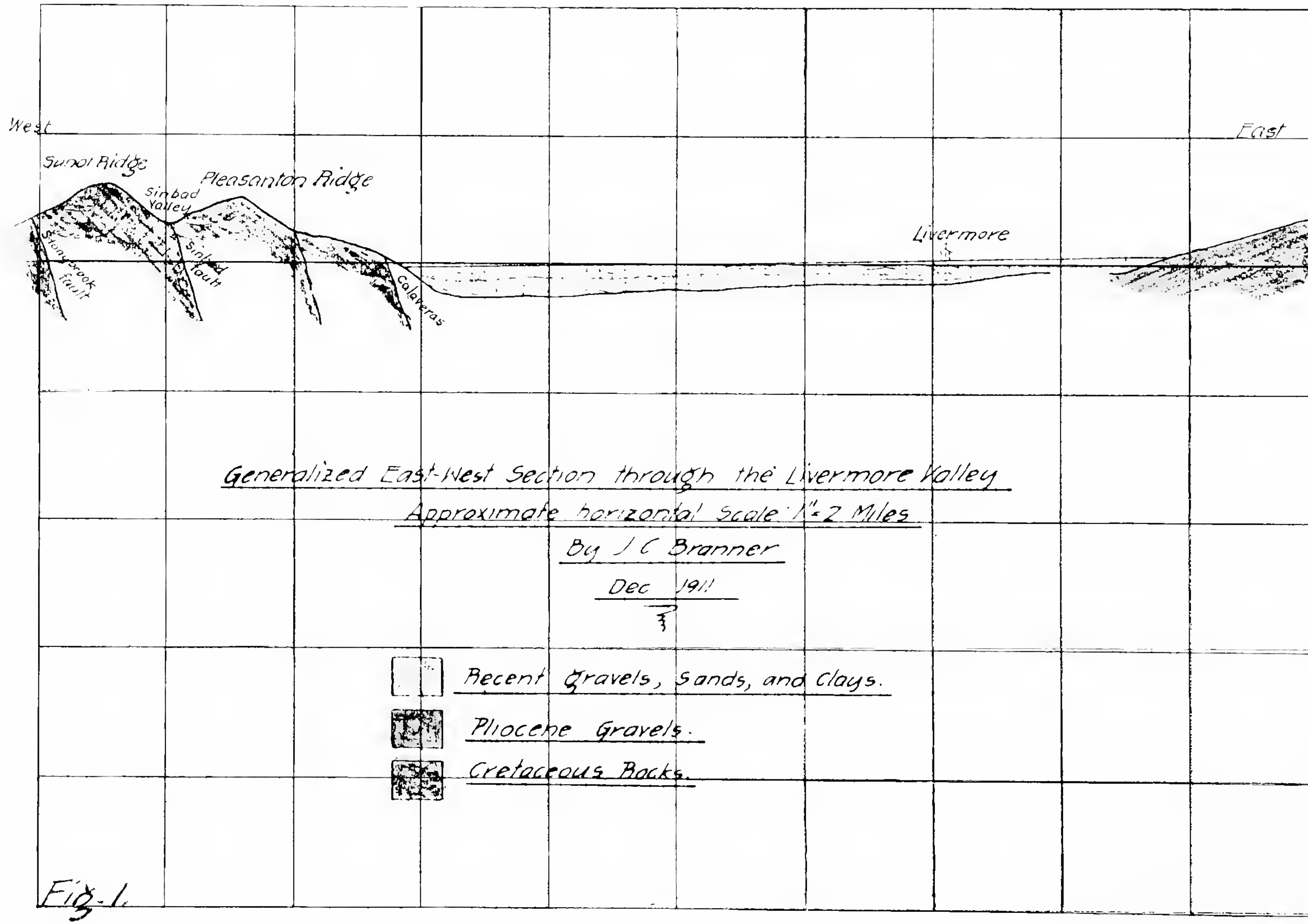
Geology of the Wells.

All of the logs of wells have been platted to scale in the hope that they would throw light upon the underground water conditions in the valley.

In some places where the wells are close together, as they are in the southwest end of the valley, at and near the pumping station, the records show the geology very well to the depth penetrated, and the layers or beds of gravel, sand, and clay can be readily identified from one well to another.

In that part of the valley lying south of Arroyo del Valle and southwest of the race track and town of Pleasanton there are records enough to show the geology to a depth of about 100 feet, but over the rest of the valley the wells are generally too far apart to do more than suggest the general character of the geology.

The materials penetrated by the wells are composed of the soils, clays, sands, and gravels that have been washed into the valley from the surrounding hills. The clays have the widest distribution and the greatest thickness; the sands are next in abundance; and the gravels are least abundant throughout the entire valley. These materials vary greatly in thickness, and alternate with each other variously.


West
East
Sunol Ridge
Sinbad Valley
Pleasanton Ridge
Stonybrook fault
Sinbad fault
Calaveras
Livermore
Generalized East-West Section through the Livermore Valley
Approximate horizontal Scale 1" = 2 Miles
By J C Branner
Dec 1911
Recent Gravels, Sands, and Clays.
Pliocene Gravels.
Cretaceous Rocks.
Fig. 1.

Inasmuch as the gravels form the principal water-bearing strata they are of especial interest and importance. The sands and clays are light enough to be moved by water having a low velocity, but the gravels are so heavy that they could be moved only by streams having strong currents.

The pockety or uneven distribution of the gravels also suggests that they have been carried to their present resting places by streams.

All the available data go to show that there is no single widespread water-bearing gravel bed beneath the valley floor. The water-bearing beds are lenticular, and more or less irregular, though they appear to follow the lines of the ancient and shifting drainage as if it had swung from one part of the valley to another.

Origin of the Material Filling the Valley.

The materials that fill the valley have been washed down from the higher ground surrounding it. This is suggested by the drainage, but it is fully borne out by the geology of the region from which the streams come. The greater part of the area draining into the valley lies to the east and southeast of the main valley.

Some of these streams go completely dry during the summer, but in the rainy season great floods pour out of the surrounding mountains and sweep into the valley enormous quantities of sands, gravels, and cobble stones.

The heaviest of these materials lodge around the margins of the valley where the streams debouch on the flat valley floor, but some of the heavy gravels are swept along the entire length of the stream channels, while the muddy waters spread over most of the valley and make the widespread deposits of finer silts.

Distribution of Rainfall.

The peculiar seasonal distribution of rainfall in this region strongly accents, and is indeed a most important factor in, this wide distribution of the coarse materials over the floor of the valley. The great volume and velocity of the streams, especially of the Mocho, and of the Arroyo del Valle, which together drain a mountainous area of something more than 215 square miles where the streams head above an elevation of 3000 feet, enables them during flood time to sweep down and out, not only the sands and gravels, but even large boulders and in large quantities.

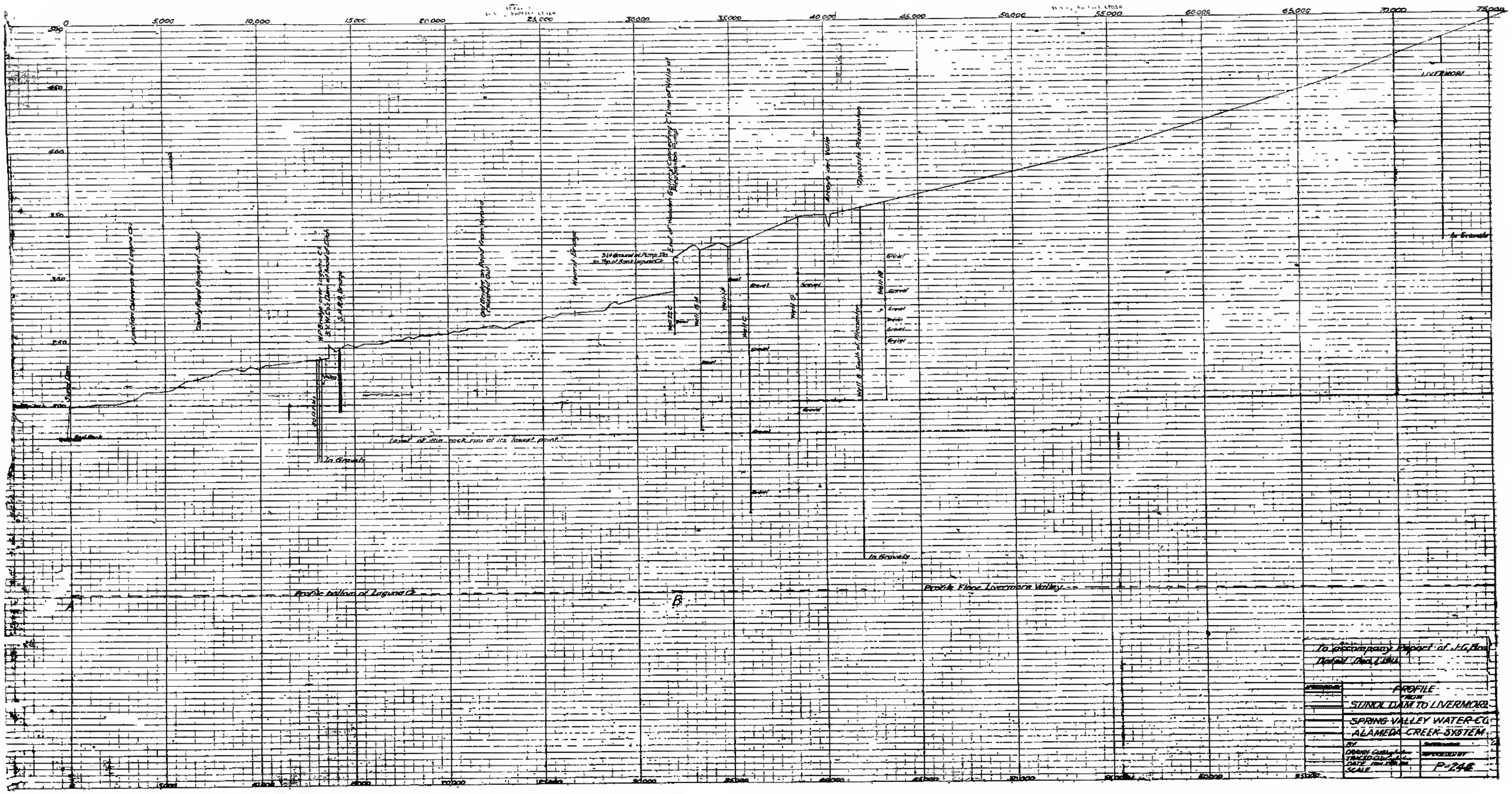
This arrangement of the materials also enables the waters that flow into the valley at other seasons of the year to sink promptly into the coarse gravels where they enter the valley region, and to gradually move toward the lowest part of the valley.

Faults Across the West End of the Valley.

The structural features of the geology of the region around the Livermore Valley have been worked out, and inasmuch as these features have an important bearing upon the amount of water naturally stored in the valley they are given here briefly.

A large fault crosses the west end of the Livermore Valley, running approximately from Verona to and past the village of Dublin. This fault I have called the Calaveras fault; it is only a small part of a great fault that extends for many miles to the northwest and the southeast. It is shown on the accompanying map by a broad broken line. There is another fault in the hills north of Sunol station, which fault follows the Sinbad Canyon toward the northwest and is here called the Sinbad fault. Still another fault that I have called the Stonybrook fault follows Stonybrook Canyon along part of its course. The positions of portions of these faults are indicated approximately on the accompanying map. All three of these faults have their downthrow on the east. The total displacement along the main fault cannot be stated exactly at present, but it is probably in the neighbrood of 2000 feet; it is certainly more than 1000 feet.

This faulting has let down the valley region east of the Pleasanton Ridge so that parts of the sand and gravel beds that are exposed about the east end of the Livermore Valley and in the hills southeast of Pleasanton, have been let down until they are carried well below the present valley floor. The general geologic structure of the valley and the hills to the west and to the southeast is shown approximately in the accompanying section. (Fig. 1.) The location of the great fault along the east face of Pleasanton Ridge leads to the assumption that the deepest part of the materials deposited



Gravels of great depth occur in Livermore Valley because of the great Calaveras-San Ramon fault line.

in the valley is along the eastern base of Pleasanton Ridge.

The Rock Rim of the Water Basin.

In order to determine the relations of the gravels in the valley east of the faults to the rock rim exposed in the Niles Canyon, a line of levels was run along the bed of Laguna Creek from the Sunol dam up to the pumping station near Pleasanton, and was connected with several of the wells put down in the valley as far east as the town of Livermore. The profile accompanies this report and is marked A-B-C. On it are placed, to the same vertical scale, the 80′ piles driven into gravels in the bed of the creek at the Western Pacific railway bridge over Laguna Creek, and a few well records near Pleasanton. These piles and well records show that the gravels east of the Sunol dam have been let down far below the level of the rock rim of the valley in Niles Canyon. Just how much lower these gravels go it is not possible to say at present.

Effect of the Faulting upon the Storage Capacity of Livermore Valley.

The downthrow of the region east of these faults has produced an unusual effect upon the water-storing capacity of the valley.

Under ordinary circumstances such a valley has a hard rock floor underlying a limited amount of water-bearing materials, and this rock floor usually slopes gently toward an outlet through which surface streams flow and the underground waters tend to drain.

In the present instance the rock floor has been lowered behind, or to the east of, the faults that converge near Sunol, thus deepening the valley itself, while the streams have continued to fill up this depression with sands, gravels, and clays washed down from the mountains. Most of the wells in the valley end in the gravels wells above the level of the rock rim; in only a few cases do the wells go lower than that rim.

It seems evident therefore that the water-storing capacity of the valley is much greater than it would be under ordinary circumstances. How much greater cannot be positively stated at present, for none of the wells, not even the deepest of them, have entered the rock floor of the valley.

Facts about Older or Pliocene Gravels.

The high gravels that rise into and form the hills south and southeast of Pleasanton are here spoken of as Pliocene, but no fossils have yet been found in them that make it possible to know their age with certainty. It is also assumed that these gravels are of fresh water origin, though for lack of fossils this also is still somewhat doubtful.

The facts about these older gravels of chief importance in the present connection are:

First, they are made up of a series of water-laid sands, gravels, and clays.

Second, the materials are mostly coarse.

Third, the general dip of the beds is toward the Livermore Valley, except in the case of beds around Vallecitos and La Costa valleys.

Fourth, they have a great thickness. The exact thickness cannot now be given, but it is more than a thousand feet.

Fifth, they cover an area of 47 square miles, though it is probable that about 15 square miles of these beds drain into the Sunol Valley.

Relation of the Older Gravels to the Water.

The character of the old gravels is such as to lead to the belief that, in those parts of the Livermore Valley where they dip beneath the later deposits that cover the valley floor, they form a large natural reservoir filled with water, and extending below the level of the valley.

Out of the 211 wells put down in the valley, the deepest has a depth of only 214 feet. Evidently this does not nearly reach the older gravels, to say nothing of penetrating their great thickness.

No Outlet by Way of San Ramon.

It has been suggested that there may be an underground outlet for the waters of the Livermore Valley northward through the San Ramon Valley.

The contour of the present surface and the relations of that surface to the outlet through the Niles Canyon make such a theory untenable. The Niles Canyon through which the waters escape from the Livermore Valley has been cut

down by the stream that flows through it just as fast as the fault has lifted the rocks across its bed. The direction of the stream was originally determined by the slope of the so-called Pliocene gravels, and it has been flowing there ever since Pliocene times.

Moreover a cross fault that passes into and under the Livermore Valley from the mountains southwest of Dublin suggests that even the underground waters are turned southward rather than northward.

Conclusions as to Geology and Water Bearing Beds of Livermore Valley.

1. The Livermore Valley is underlain by water-bearing beds to a depth that has not been penetrated by any of the wells put down.

2. There is no single water-bearing stratum, but there are many water-bearing beds of sands and gravels that are irregular in thickness and form.

3. Around the margins of the valley, and especially about the east and southeast sides whence most of the waters come, the materials deposited by the streams are coarse, and the water sinks into these beds promptly.

4. The up stream ends of these beds of coarse materials form the intake for the surface waters.

5. The old river channels and the beds of gravels and sands form irregular underground channels along which the waters pass.

6. The underground waters pass slowly toward the outlet of the valley, though, owing to the nature of the beds through which they move, their courses and velocities may vary considerably by the way.

7. The groups of wells of the Spring Valley Water Company near the lower end of the valley are so located as to get much of this underground water from the shallower beds, but from the structure and history of the valley, it appears that the supply available is much larger than that which is now being taken out.

8. The water-storing capacity of the Livermore Valley is enormously larger than would be formed under ordinary climatic and geologic conditions.

9. The unusual depth of the water-bearing beds in the valley is due to their having been let far down behind the edge of the rock basin that forms the lip or outlet of the valley in the Niles Canyon.

10. The water-storing capacity of the valley is further increased by the concentration of rainfall in this region. This concentration of the rainfall makes the creeks very large when they are running, while the steep grades of the mountain streams enable them to carry down and spread widely over the valley floor unusually coarse materials. Into these coarse materials the water from the streams sinks during the whole year.

11. The group of faults across the west end of the valley shuts in all of the water below the level of the rock floor at the Sunol dam of the Spring Valley Water Company.

12. The older gravels that underlie the large part of the valley still further increase the underground storage capacity of the basin.

13. There is here a great natural reservoir of unknown dimensions which can be drawn upon in case of emergency with the assurance that the water will be restored in seasons of heavy rainfall.

14. I know of no reason for supposing that water is escaping northward from the Livermore Valley basin by way of the San Ramon Valley.

15. It is quite possible that further geologic studies may develop the fact that deep artesian wells may be found by sinking into the older gravels near the foot of the hills east of Pleasanton.

Yours truly,

J. C. BRANNER,
Consulting Geologist.

REPORT ON THE UNDERGROUND WATER CONDITIONS OF THE LIVERMORE VALLEY AND OF SUNOL VALLEY

BY

DR. J. C. BRANNER,

Vice-President of Stanford University and in charge of the Department of Geology.

Stanford University, California.
May 6, 1912.

Spring Valley Water Company, San Francisco, Cal.

Gentlemen:

Since my preliminary report made to you December 1, 1911, upon the underground water conditions of the Livermore Valley, I have done, and have had done under my own direction, a good deal of field work on the geology of the region with a view to testing out the statements made by me in that report, and to the further comprehension of the geology of the Livermore and Sunol valleys, with especial reference to underground water.

Work Done.

Several years ago the general geology of the area covered by the Pleasanton, Tesla, Mt. Hamilton, and San Jose topographic sheets of the U. S. Geological Survey was worked out by me and by my colleagues and assistants in the department of geology of Stanford University. During the last seven months especial attention has been given to the study of the geology of the Tesla and Pleasanton areas with reference to the underground water conditions in the Livermore and Sunol valleys. In this work I have had the help of two assistants in the field as it was required in addition to the co-operation of the engineers of the Company in running lines of levels, the collection of data, drafting, etc.

I have received from the Company's office 157 logs of wells put down about Pleasanton, and more than fifty additional logs have been collected in the vicinity of the town of Livermore and along the northern margin of the Livermore valley.

All of these data have been taken into consideration in reaching the conclusions here presented.

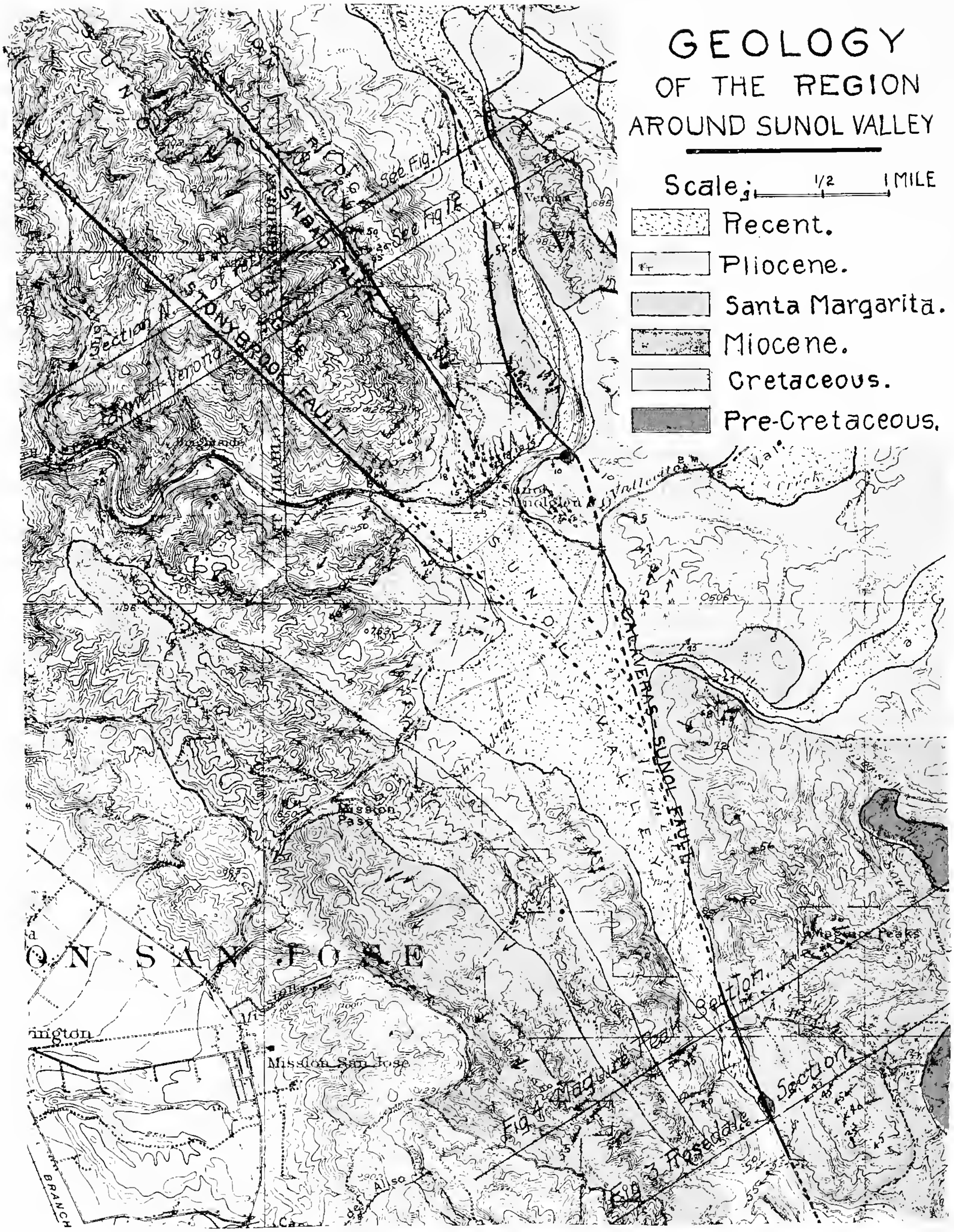
Wells in the Livermore Valley.

The total area of the flat floored part of the Livermore Valley is about 58 square miles Within this area, but scattered irregularly over it, more than 200 wells have been put down; of these wells I have the logs of 211. They average 82.7 feet in depth. Of the three deepest one of 212 feet is in the town of Livermore; another of 214 feet is near the race-track just west of Pleasanton; a third, just south of Pleasanton, is 275 feet deep.

A remarkable fact in regard to these wells is that they are all in loose materials of one kind or another, not one of them having reached the hard rock floor of the valley.

Deductions from the Well Records.

The logs of all the wells have been platted to scale in the hope that they would throw much light upon the underground water conditions within the valley. In the southwest end of the valley near the pumping station, where the wells are close together, the logs show the underground geology well to the depth penetrated, and the


GEOLOGY
OF THE REGION
AROUND SUNOL VALLEY
Scale; 1/2 1 MILE
Recent.
Pliocene.
Santa Margarita.
Miocene.
Cretaceous.
Pre-Cretaceous.
SUNOL VALLEY
CALAVERAS-SUNOL FAULT
STONYBROOK FAULT
SINBAD FAULT
Mission Pass
Mission San Jose
Sunol
Monument Peaks
See Fig. 11
See Fig. 12
Fig. 3 Rosedale Section
Fig. 4 Flagstaff Peak Section

beds of gravel, sand, and clay can readily be identified from one well to another.

In the part of the valley lying south of Arroyo del Valle and southwest of the Pleasanton race-track there are records enough to show the geology to a depth of one hundred feet; but over the rest of the Livermore Valley the wells are too far apart to do more than to suggest the general character of the geology. The logs of the wells show that the materials penetrated are soils, clays, sands, and gravels. The characters of these materials show that they have been washed into the valley from the surrounding hills and mountains.

The clays have the widest distribution and the greatest thickness; the sands are second in abundance and thickness; while the gravels are least abundant throughout the valley as a whole, and the gravel beds are less constant in thickness and have a smaller areal distribution than the other materials.

All of these materials vary greatly in thickness and alternate with each other irregularly.

The sands and clays are light enough to be moved by water having a low velocity, but the coarse gravels are so heavy that they could be moved only by streams having strong currents. And, as, in this series of deposits, the gravels form the principal water-bearing strata, they are of especial interest and importance in connection with the present report.

All of the available data go to show that there is no single widespread water-bearing gravel bed beneath the valley floor. The water-bearing beds are more or less lenticular in form and more or less irregular in width, thickness, and direction. They appear to follow the ancient shifting stream courses as they swung from one part of the valley to another.

Origin of the Materials Filling the Valley.

The materials that fill the valley basin have been washed down from the higher ground surrounding it. Most of the coarse materials have come, either directly or indirectly, from the high mountainous region around the head waters of the Mocho and Arroyo del Valle whose drainage basins lie to the east and southeast of the main valley. Much of it has come from an old series of gravels that form the high hills immediately south of Pleasanton and Livermore.

The geographical and geological conditions under which the gravels accumulated have had such an important influence upon the character of the deposits themselves, and upon their water-bearing capacity, that it is important to consider in this connection what those conditions have been, and in what way they have affected the gravels and other water-bearing beds of the Livermore Valley.

Distribution of the Rainfall.

The peculiar seasonal distribution of the rainfall in this region accents in a remarkable manner, and is indeed an important factor in, the wide distribution of the coarse materials over the floor of the Livermore Valley. Without going into details it is only necessary to call attention to the well-known fact that the rainfall in the region under consideration is usually concentrated into three or four months of the year.

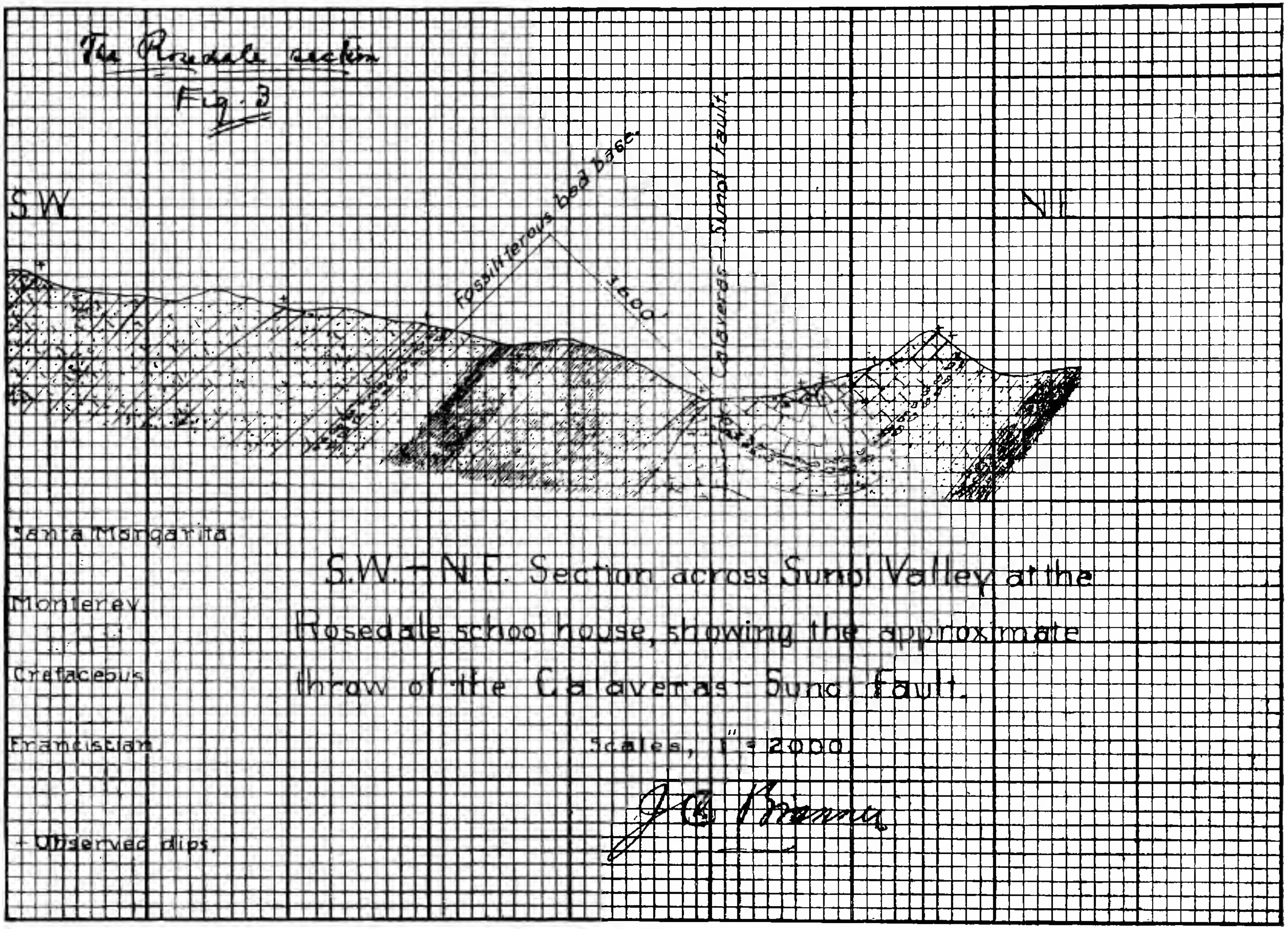
The Mocho and Arroyo del Valle drain an area of something more than 215 square miles, and these streams head in mountains more than 3000 feet high. (See map, page 202a.) The result of this combination of a concentrated rainfall and a steep mountainous topography is that the weak streams of the dry summer and fall months are commonly swollen to powerful mountain torrents during the rainy season.

The Conditions During the Glacial Epoch.

The concentration of the run-off was further emphasized during the glacial epoch by the geographic conditions of that period. At that time the Mt. Hamilton range, and the entire area of the state stood at a much greater elevation, and the winter precipitation in the high mountains around the Livermore Valley was largely in the form of snow. In the spring the snows must have gone off rapidly with the early spring rains, so that the streams were very much larger during the glacial epoch than they are now when there is much less snow on these particular mountains than formerly.

Effect of the Concentrated Run-off on the Water-Bearing Gravels.

The great increase in volume and velocity of the streams, both during the glacial epoch and since then, has enabled them to sweep down into



The Rosedale section
Fig. 3
S.W.
N.E.
Fossiliferous bed base.
1600'
Calaveras — Sunol fault.
Santa Margarita.
Monterey.
Cretaceous.
Franciscian.
+ Observed dips.
S.W. — N.E. Section across Sunol Valley at the
Rosedale school house, showing the approximate
throw of the Calaveras - Sunol fault.
Scales, 1" = 2000
J. C. Branner

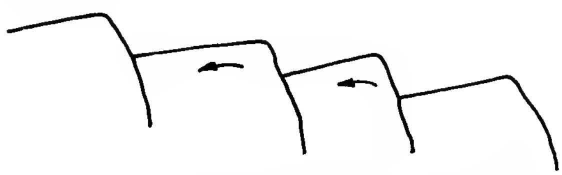

Maguire Peak section
Fig 4
S.W.
Mission Peak Ridge.
NE.
Maguire Peak
3400
+ Observed dips.
Santa Margarita.
Monterey.
Cretaceous.
Franciscian.
S.W.–N.E. Section from Mission Peak Ridge to Maguire Peaks,
showing the approximate throw of the Calaveras – Sunol fault.
Scales, 1" = 2000.

the valley enormous quantities of the loose and coarse materials picked up along their channels. On reaching the edges of the flat valley, the velocity of the streams is checked and the heaviest of these materials are dropped, but even the heavy gravels and coarse sands are carried far down the streams and spread over the valley floor. This arrangement of the loose materials with the coarser portions around the margin of the valley is highly favorable for receiving and retaining water. At all seasons of the year the waters flowing into the valley sink promptly into these coarse beds as soon as they enter the flat region and move slowly toward the lowest part of the valley. The fact that this process has been in operation since the early part of the glacial epoch suggests a great thickness and a wide distribution of the coarse water-bearing beds in the Livermore Valley.

Fault Across the West End of the Valley.

The geologic structure of the region around the Livermore Valley has been worked out, and such of those features as bear upon the water-bearing deposits of the valley are here given briefly.

The sequence of the rocks, their structure, and their relations to each other show that a great vertical fault or displacement of the rocks passes across the region under consideration. It is not meant that the fault blocks were lifted or depressed vertically, but that a relative vertical movement was produced by a slight westward tipping or revolving of the fault blocks.



We have called this the Calaveras-Sunol fault. At the south edge of the Pleasanton sheet this fault appears where the road from the Calaveras Valley passes northward over the divide to Alameda Creek. From this point it follows northward down Alameda Creek toward Sunol, crosses Laguna Creek just west of the Southern Pacific railway bridge, passes up on the east side of Pleasanton Ridge for a mile, descends to Laguna Creek near Verona station, and follows thence along the east base of Pleasanton Ridge in the direction of Dublin. To the east of this fault line the westward tipping or revolving of the faulted block caused a westward tilt of the old surface or valley floor. Possibly this obstruction was formed in part by an uplift on the west side of this fault; in any case the movement along the fault produced a great natural rock barrier across the west end of the Livermore Valley.

The formation of a great natural water storage reservoir in this manner is so unusual that it seems advisable to set forth briefly some of the reasons for the conclusions reached.

Geologic sections have been worked out at several places and the results are shown on the accompanying sections.

The Rosedale section (Fig. 3) shows the structure across the fault at Rosedale school house at the extreme southern end of the Sunol Valley. The profile given is the true profile as taken from the topographic sheet. The sequence of the beds and the structural features are taken from direct observations made for the specific purpose of determining the amount of this displacement. The horizon from which measurements were made is a very fossiliferous and readily identified Tertiary bed that seems to be constant over the area involved. The dips of the beds as shown in the section are the true dips as observed at the surface.

This section shows that the downthrow along the fault at this place is on the east, and that the vertical displacement amounts to about 3600 feet.

The Maguire Peak section across the fault (Fig. 4), about a mile further north and nearly parallel with the Rosedale section, passes through Mission Peak Ridge and Maguire Peak. the high peak of the cluster east of the Sunol Valley. This section exhibits the same series of rocks and nearly the same structure.

This Maguire Peak section shows that the downthrow on the fault is on the east, and that the vertical displacement is about 3400 feet.

Although the Calaveras-Sunol fault continues northward along the east base of the Pleasanton Ridge, the absence of an easily recognizable bed or horizon in the Pleasanton Ridge or in the mountains west of there makes it difficult or impossible to determine exactly the

amount of the displacement along the western edge of the Livermore Valley.

The area of Santa Margarita Tertiary beds exposed with their steep west dips in the Western Pacific railway cut near Verona station, and the occurrence of beds of the same series at the Southern Pacific bridge about a mile northeast of Sunol station and dipping steeply westward toward the Pleasanton Ridge, show that the fault crosses Laguna Creek not far below the bridge mentioned, that the downthrow is still on the east side, and that the displacement must be something more than the height of the Pleasanton Ridge, that is, it is clearly more than 1000 feet. (See Figs. 11 and 12, page 220.)

But the rocks forming the crest of Pleasanton Ridge are all Cretaceous, while the Tertiary beds that formerly covered them have all been removed from the ridge west of Verona station, and the Tertiary beds exposed at the Southern Pacific railway bridge are the tuffs at or near the top of the marine Tertiary of this region. The amount of the displacement on the fault at the Southern Pacific bridge therefore is equal, at least, to the height of Pleasanton Ridge above the Tertiary tuffs increased by the total thickness of the Santa Margarita Tertiary beds and by an unknown thickness that has been removed by erosion from the top of the ridge.

The thickness of the Santa Margarita Tertiary beds as shown in the Maguire Peak section is at least 2500 feet: the height of Pleasanton Ridge above the Tertiary tuffs is about 1000 feet (see topographic map, page 210). The total vertical displacement on the western edge of the Livermore Valley near Verona is therefore 3500 feet plus an unknown additional amount.

These amounts are so close to those obtained from the Maguire Peak and Rosedale sections across the fault at the south end of the Sunol Valley that they must be accepted as very near the truth.

A downthrow of 3000 feet on the east side of the fault about the southwest corner of the Livermore Valley may therefore be regarded as a conservative estimate.

Bearing of the Sunol-Calaveras Fault upon the Water-Bearing Gravels of the Livermore Valley.

Ordinarily mountain valleys have hard rock floors with a limited amount of loose material spread over them in the form of sands, gravels, clays and soils. The rock floors of such valleys usually slope gently toward an outlet through which surface streams flow, and toward which the underground waters tend to drain. In the case of the Livermore Valley, however, the rock floor has been let down along its western margin, and especially about its southwest corner, until it has been carried down fully 3000 feet below its former position. It is not meant to imply, however, that the valley has been filled up to a depth of 3000 feet with gravel. Faulting might occur and still leave the valley floor of hard rock and covered like other valleys, with only a thin veneer of loose materials.

Other evidence, however, goes to show that the fault *has* let the old rock floor down to a considerable depth below the rock rim over which Laguna Creek flows through Niles Canyon.

The Rock Rim of the Livermore Water-Basin.

Laguna Creek, the stream that drains the Livermore Valley, runs over a hard rock bed in the lower or western end of the Niles Canyon. This rock bed is exposed here and there as far east as the Spring Valley Water Company's dam three-quarters of a mile west of Sunol station. From this dam upstream the rock bed is nowhere else exposed along the stream for seven or eight miles above the town of Pleasanton on the Arroyo del Valle, and for six or seven miles above Livermore on the Mocho.

Depth of the Gravels in the Livermore Valley.

The deepest wells put down in the Livermore Valley have penetrated the gravels and accompanying beds to a depth of 275 feet. The question arises as to the relations of the bottom of this and other deep wells to the rock rim of the basin at the Sunol dam.

A line of levels for the purpose of determining these relations was run along the bed of Laguna Creek from the Sunol dam to the pumping station near Pleasanton, and this line was connected with the wells as far east as Livermore, and also with the piles driven into the bed of Laguna Creek for the foundations of the bridge piers where the Western Pacific railway

crosses it above Sunol. These piles are said to have penetrated the gravels to a depth of 80 feet. The profile of the creek bed, the rock rim at the dam, some of the deep wells in the valley, and the depth of the piles at the Western Pacific bridge are all shown on the accompanying section. (Page 206.)

This section makes plain the fact that the gravels of the Livermore Valley have been let down to a considerable depth below the rock floor or rock rim where it is exposed in the bed of the stream in Niles Canyon.

Data are lacking at present for the precise determination of the depth of the gravels in the Livermore Valley. They certainly and greatly exceed the depth of the deepest wells thus far put down in them.

This subject will be taken up again in connection with the subject of the Pliocene gravels.

The Older or Pliocene Gravels.

The hills south and southeast of Pleasanton, and certain hills south and southeast of Livermore are shown on the accompanying map as being made up of Pliocene deposits—interbedded sands, clays and gravels, many of the beds being of very coarse materials. (Page 202a.)

Fossils found within 340 feet of the base of the series at Cresta Blanca on Arroyo del Valle and elsewhere show that they are of fresh water or land origin.

Erosion has cut into them on the hills so that fully 250 feet of their thickness is openly exposed at several places. Through the hills south and southeast of Pleasanton these gravel beds dip uniformly toward and beneath the Livermore Valley at an angle varying from 20° to 23°.

In order to show the approximate thickness and the structural relations of these gravels to the Livermore Valley a profile has been drawn to scale from the top of the ridge southeast of Pleasanton to Eliot station in the valley (Fig. 6), and another has been drawn from the crest of the same ridge northeastward to the county bridge over Arroyo del Valle (Fig. 7). The dips of the beds as observed in the field have been put on these profiles so as to exhibit the general geologic structure.

Although these sections do not include either the lowest or the highest beds of this series of deposits, *the total thickness of these Pliocene deposits here exhibited amounts to considerably more than* 4000 *feet.*

An isolated remnant of these same gravels half a mile west of Livermore leads to the conclusion that they extend far out beneath the valley, but the absence of the beds from the north side of the valley shows that they do not pass entirely across it.

These facts taken in connection with the geology worked out on higher ground west of the valley, lead to the inference that there is probably an east-west fault crossing the Livermore Valley from somewhere in the vicinity of Dublin passing about through the town of Livermore and eastward in the direction of Arroyo Seco. The downthrow of this fault is on the south side and is probably greatest about two and a half miles north of Pleasanton and a mile and a quarter north of Eliot, while it dies out or has a less throw at its extremities to the east and west.

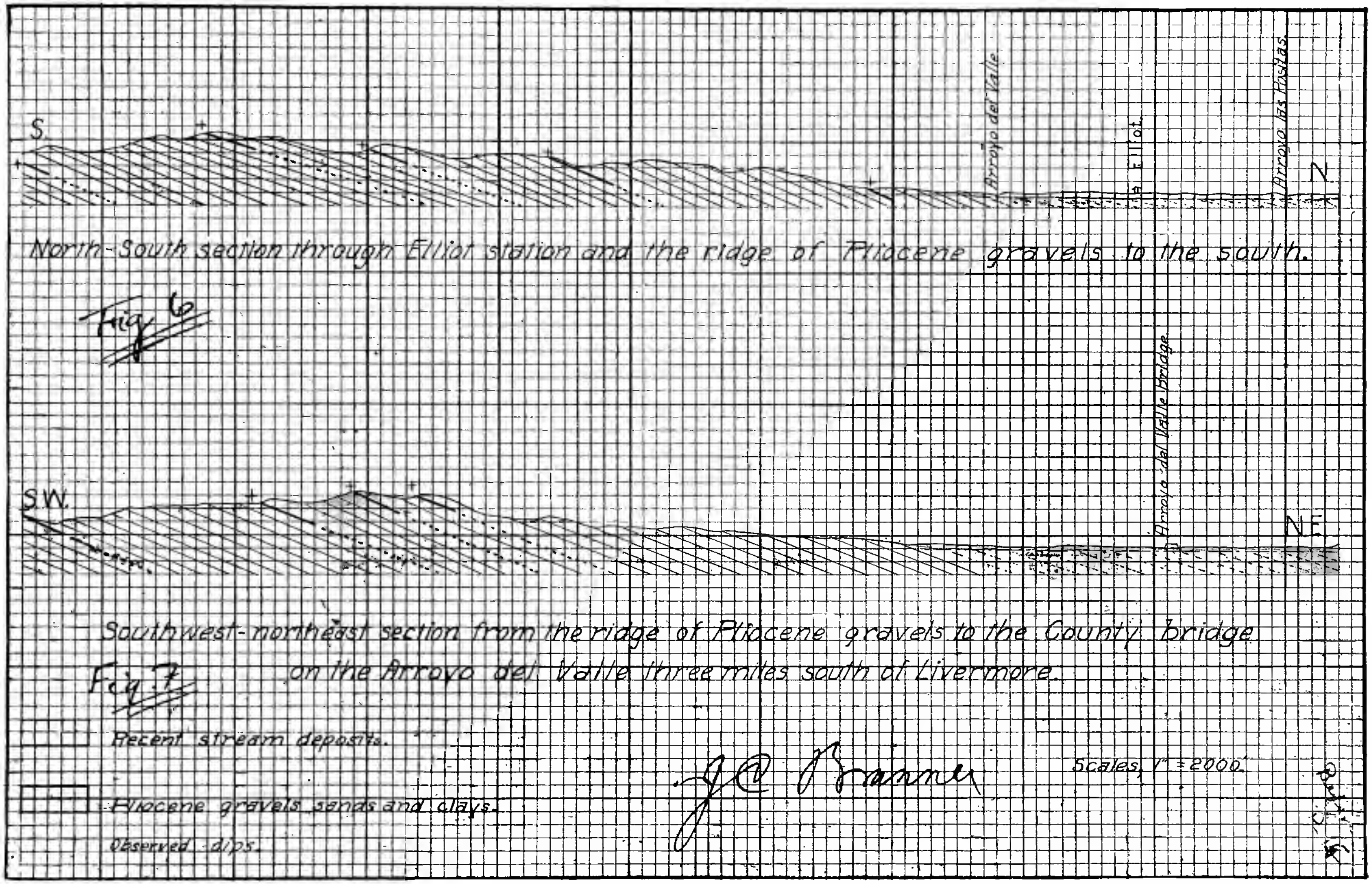
The facts of chief importance in regard to these Pliocene gravels in this connection are:

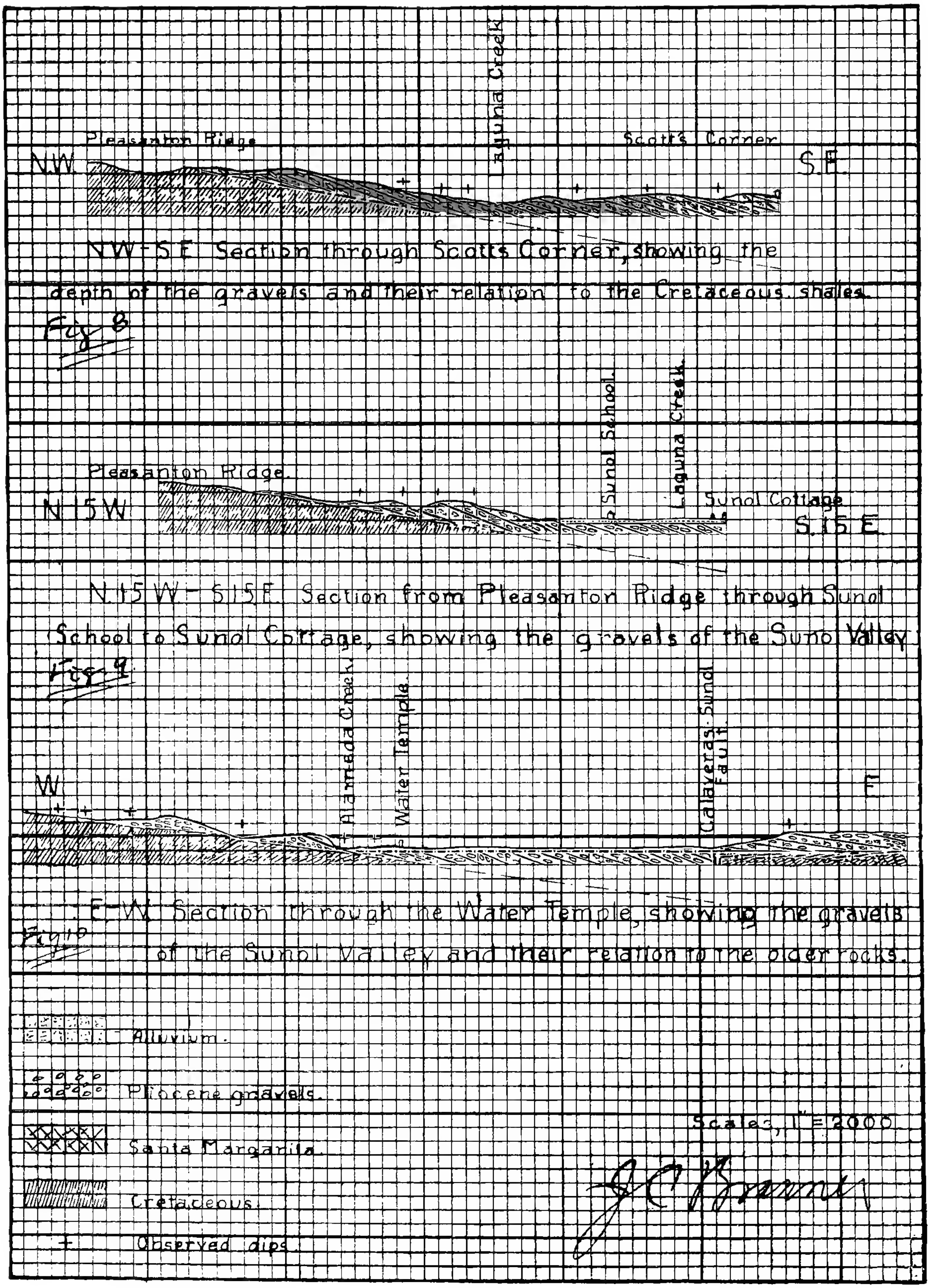
1. They are mostly coarse water laid materials such as are likely to be water-bearing under cover.
2. Over an area of 47 square miles they dip towards and beneath the Livermore Valley at an angle of about 20°.
3. They have a thickness of more than 4000 feet.
4. It seems probable that deep wells properly located with reference to the geology, and penetrating these gravels where they pass beneath the valley, may yield artesian water.
5. They are of fresh water or land origin
6. Even if these gravels do not yield artesian water, they form a great natural reservoir beneath the valley.
7. There is no great thickness of gravels along the northern margin of the valley.

No Outlet by Way of San Ramon.

The possibility has been suggested of an underground outlet for the waters of the Livermore Valley northward by way of the San Ramon Valley.

I know of no good grounds for this idea. The Niles Canyon through which the drainage of the Livermore Valley escapes has been cut down by the stream flowing through it. The


S.
Arroyo del Valle
Elliot
Arroyo las Positas
N
North-South section through Elliot station and the ridge of Pliocene gravels to the south.
Fig. 6
SW.
Arroyo del Valle Bridge
NE
Southwest-northeast section from the ridge of Pliocene gravels to the County bridge
on the Arroyo del Valle three miles south of Livermore.
Fig. 7
Recent stream deposits.
Pliocene gravels sands and clays.
Observed dips.
J C Branner
Scales, 1" = 2000'


Laguna Creek
Pleasanton Ridge
Scott's Corner
NW
S.E.
NW-S.E. Section through Scotts Corner, showing the depth of the gravels and their relation to the Cretaceous shales.
Fig 8
Sunol School.
Laguna Creek
Pleasanton Ridge.
Sunol Cottage
N 15 W
S. 15 E.
N. 15 W - S 15 E. Section from Pleasanton Ridge through Sunol School to Sunol Cottage, showing the gravels of the Sunol Valley
Fig 9
Alameda Creek
Water Temple.
Calaveras-Sunol Fault.
W
E
E-W. Section through the Water Temple, showing the gravels of the Sunol Valley and their relation to the older rocks.
Fig 10
Alluvium.
Pliocene gravels.
Santa Margarita.
Cretaceous.
Observed dips.
Scales, 1" = 2000
J C Branner

position of the stream was apparently determined by the original slope of the Pliocene gravels, and it has been flowing there ever since those gravels were deposited.

The Gravels About Sunol.

In the vicinity of Sunol the Pliocene gravels are exposed in the hills north, east and southeast of the town, and in the bluff near the water temple three quarters of a mile southwest of the station. In the Sunol and Pleasanton ridges north of the town and in the ridge southwest of the town these gravels rest upon folded Cretaceous shales. In the hills east of the town they rest for the most part on the folded fossiliferous Tertiary beds like those exposed in the Maguire Peak region and east of Verona station. The arrangement of the cobbles in the best exposed of the gravel beds shows that the streams in which they were laid down were flowing westward or in the direction of the Niles Canyon. At present the beds do not dip in that direction. In the bluff near the water temple the dip is toward the east at an angle of seventeen degrees. (Fig. 10.) It is just possible this is not a true dip, but that it is caused by a dislocation of the beds. However, in Pleasanton Ridge the dips are nearly south at an angle of about 17°; from the Pleasanton Ridge to Scott's corner the dip is toward southeast at an angle of from 16° to 20°. (Fig. 8.) If, as it seems, these beds were deposited while the water flowed westward or toward Niles Canyon, there has been a depression along the east side of Sunol Valley since the deposition of the gravels.

If it be assumed that the streams in which the gravels were laid down had a slope of about two degrees,* then there has been a depression that has let the gravels down about 1200 feet in the deepest part of the Sunol Valley.

The question of the depth of the gravels in the Sunol Valley may also be approached from the point of view that the surface of Cretaceous shales on which they were laid down was an approximately even one, and that the dips of the gravels continue unchanged beneath the valley. This old Cretaceous surface is tolerably clear in the Pleasanton Ridge. It there slopes toward the Sunol Valley as shown in the accompanying Sunol Valley sections. (Figs. 8, 9 and 10.)

If this old surface continues, as it appears to do, and if the gravels beneath the valley have the same dips as they do on the hills, the gravels are deepest in the Sunol Valley about a fifth of a mile southwest of Scott's corner where they have a depth of from 600 to 900 feet.

It seems probable that these deep Pliocene gravels of the Sunol Valley are of sufficient thickness to form an important water basin. If the structure is what the facts seem to indicate, wells, in order to penetrate these beds, should not be put down south of the mouth of San Antonio Creek unless developments show the geology to be different from what it now appears to be.

The most promising locality seems to be between Scott's corner and the Spring Valley cottages and from 500 to 1000 feet southwest of the public road.

Stonybrook and Sinbad Faults.

It has been pointed out that the displacement along the Sunol-Calaveras fault has the downthrow on the east at this place.

The theory of a depression in the gravels *west* of the fault line seems to be in conflict with the former statement.

It should be noted, however, that the downthrow on the east side of the Sunol-Calaveras fault is a very large one, amounting to more than 3000 feet, while the depresssion in the Sunol Valley seems to be local and to amount to only about one thousand feet.

Furthermore the geology of the region north of the Niles Canyon shows that besides the Sunol-Calaveras fault that passes along the east side of the Sunol Valley, and along the west side of the Livermore Valley, two other faults, the Stonybrook fault and the Sinbad fault, converge in the northern end of the Sunol Valley. (Page 210.) The position and structure of these faults are shown on the accompanying geologic sections across the Sunol and Pleasanton ridges. (Figs. 11 and 12.)

Geology of Sunol Valley only Remotely Related to that of Livermore Valley.

The geology of the area where these faults

*The highest angle obtained on the stream beds in the Livermore Valley is on the Mocho just below the Mocho school house, where it is about one degree.

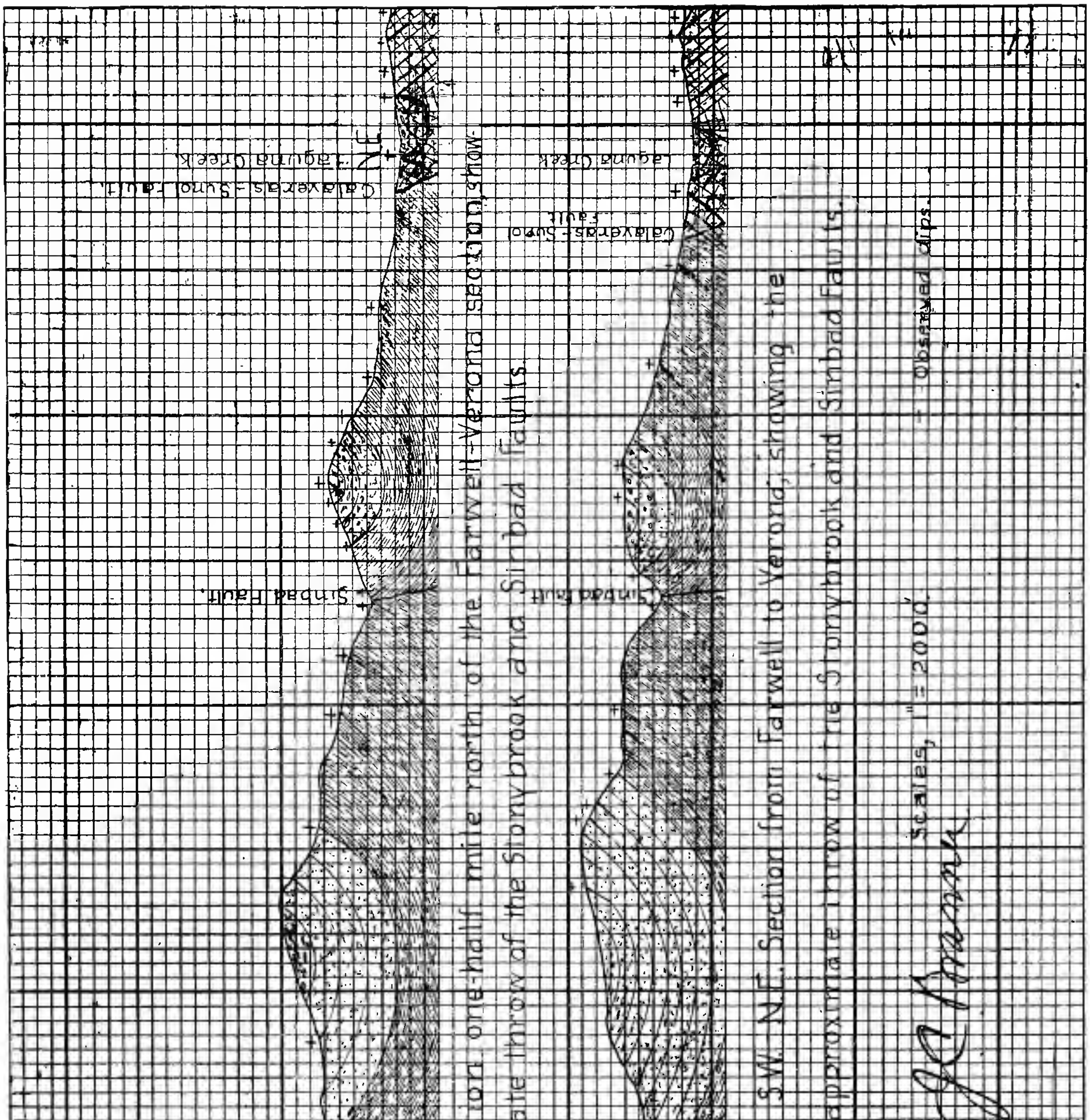


Fig. 11
SW
Stonybrook Fault.
Sinbad Fault.
Calaveras-Sunol Fault.
Laguna Creek
NE
SW. NE Section one-half mile north of the Farwell-Verona section, showing the approximate throw of the Stonybrook and Sinbad Faults.
Fig. 12
Stonybrook Fault
Sinbad Fault
Calaveras-Sunol Fault
Laguna Creek
SW. NE. Section from Farwell to Verona, showing the approximate throw of the Stonybrook and Sinbad Faults.
Gravels.
Santa Margarita
Cretaceous
Scales, 1" = 2000'.
+ Observed dips.

converge is necessarily complicated in addition to being concealed beneath the wash in the valley. It seems probable that the deep gravels do not extend south of the mouth of San Antonio Creek; in other words, they underlie only the northern half of the Sunol Valley.

The geology of the Sunol Valley is only remotely related to that of the Livermore Valley.

Conclusions as to Geology and Water Storing Capacity of Livermore and Sunol Valleys.

1. The geologic structure and the history of the Livermore Valley show it to be a very unusual valley in regard to its water storing capacity which is much greater than it would be under ordinary geologic and climatic conditions.

2. It contains two distinct sets of water-bearing beds, and possibly three.

3. The newest beds are those recently washed into the valley from the surrounding mountains.

4. Beneath and merging into these new beds are probably wide spread and deep deposits of gravels and sands washed into the valley during the uplift and heavy run-off of the glacial epoch.

5. Still older beds of Pliocene Tertiary age form the high hills south and southeast of Pleasanton and Livermore, and dip far beneath the floor of the valley.

6. These Pliocene gravels have a thickness of 4000 feet or more.

7. They are of land or fresh water origin.

8. An east-west fault, from somewhere near Dublin and passing about under the town of Livermore, seems to have let the northern end of these beds down to a great depth beneath the valley.

9. The northern ends of the Pliocene gravel beds are concealed beneath the later gravels washed into the valley during and since the glacial epoch.

10. The later deposits in the valley contain many water-bearing beds of sands and gravels, but they are irregular in form and thickness so that there is no single definite bed from which wells receive their waters.

11. Around the margins of the valley, and especially about the eastern and southeastern sides whence most of the water comes, the stream-deposited materials are coarse, and the water sinks into them promptly.

12. The water-storing capacity of these newer deposits is increased by the steep topography of the region drained and by the concentration of the rainfall which make the streams very large for a short period during the year, and thus enables them to carry down and spread over the valley coarse materials. Into these beds the water from the streams sinks during the whole year, and moves toward the outlet of the valley.

13. The groups of wells of the Spring Valley Water Company near the lower end of the valley are so located as to get much of this underground water from the shallower beds, but the geology of the valley leads to the belief that the available supply is very much larger than that which is now being pumped.

14. A great fault across the west end of the valley and crossing Laguna Creek three-quarters of a mile above Sunol station, has let down the region east of it three thousand feet or more.

15. This fault has carried the water-bearing gravels of the Livermore Valley down far below the level of the rock floor exposed in the Niles Canyon at the Sunol dam.

16. The Livermore Valley is therefore an enormous natural reservoir of unusual origin and unknown dimensions that can be drawn upon in case of emergency with the assurance that the water will be restored in seasons of heavy rainfall.

17. I know of no reason for supposing that the water is escaping northward from the Livermore Valley by way of the San Ramon Valley.

18. It is quite possible that deep artesian wells may be obtained by sinking in the deep Pliocene gravels near the south margin of the valley.

19. The geologic structure of the Sunol Valley shows that the Pliocene gravels that cap the surrounding hills dip beneath the northern end of that valley and form a basin the center of which is from 500 to 1000 feet southwest of Scott's corner.

20. The gravels in the center of this Sunol

basin probably have a thickness of from 600 to 900 feet or even more.

21. The deep gravels underlie only the northern half of the Sunol Valley.

22. Whether the deep gravels of the Sunol basin form a valuable reservoir can only be determined by practical tests.

Respectfully,

J. C. BRANNER.

Illustrations Accompanying Report of May 6, 1912, of Prof. J. C. Branner, on Underground Water Conditions of the Livermore Valley and of the Sunol Valley.

REPORT ON THE GEOLOGY AND THE UNDERGROUND WATER SUPPLY OF LIVERMORE VALLEY

BY

DR. ANDREW C. LAWSON,

In charge of Department of Geology, University of California.

Berkeley, Cal., May 31, 1912.

Mr. S. P. Eastman, Vice President Spring Valley Water Co.,
San Francisco.

Dear Sir:

I have read Professor J. C. Branner's report of May 6, 1912, on the underground water conditions of Livermore Valley and of Sunol Valley, and with his observations and conclusions in mind have examined the territory with which that report deals. My examination has been limited to a rapid review of the salient features of the geology and I have made no attempt at detailed mapping of geological boundaries. The maps and sections which accompany Professor Branner's report and my own familiarity with this field have greatly aided me in the examination, and I have been able to reach conclusions which I feel well justified in putting forward, notwithstanding the limited time given to the present field work.

Methods of Study.

It would be rather remarkable if any two geologists acting independently, as Professor Branner and I have done, should agree at all points in the interpretation of the phenomena presented by this most interesting and somewhat complicated field. If we had both precisely the same geological experience there would still be room for differences of opinion due to the personal equation in all those questions in which data necessary for a settled conclusion are only partially obtainable. But Professor Branner's experiences in the general field of geology have been different from my own and with reference to this particular field he has approached it from one side and I from the other. We therefore come to the consideration of the problems raised in the Livermore Valley with quite naturally different points of view. Professor Branner is more familiar with the stratigraphy, structure and geological history of the region south of Livermore Valley; while I, on the other hand, have a greater familiarity with the geology of the country north of the valley.

I mention these matters so that if, in reading the remarks which follow, you detect here and there observations or opinions which seem to differ from those expressed by Professor Branner in his very excellent and most valuable report, you will not be unduly surprised. Such differences are usual and, indeed, in complicated fields where full data necessary for sure inference are difficult to obtain they are inevitable. It would be a miracle if any two geologists should study quite independently any complicated field and arrive at the same conclusion on all phases of its problems. The usual procedure, and the way in which science makes progress, is for one geologist to study the field, map its formations, interpret its structure and write its geological history. These results he presents to the geological world for criticism and correction. If the field is sufficiently interesting he will get these in abundance. Geological science, like most other sciences, adds to its certitudes quite as much by criticism and correction of error as by original effort to ascertain the truth. Both functions are necessary; for no man's statements are scientific unless they are verifiable, and science is after all but the concensus of expert opinion.

Concurs With Prof. Branner's General Conclusions.

With this preface, which is intended to forestall any anticipation on your part of a complete agreement between Professor Branner's observations and deductions and my own, I hasten to say that I entirely concur with him in certain general conclusions, which, I take it, are from your point of view, the most important in his report.

I agree with him in his conclusion:

1. That Livermore Valley is an underground storage reservoir of exceptional and remarkable structure.

2. That it is underlain by two series of formations, one of Pliocene age and one of an age extending into the present, both of which have a large proportion of gravel in them.

3. That these gravels afford a great storage space for underground water.

4. That these formations lie in a basin which is enclosed on all sides by older and practically impermeable rock.

5. That the rocks of Pleasanton Ridge, which bounds the basin on the west, are an effective barrier to the escape of those waters below a certain level determined by the outlet of the drainage of Alameda Creek.

6. That this hard rock barrier preventing the escape of the stored waters below the level referred to is the remarkable and exceptional feature of the basin.

7. That this relation of the sediment-filled basin to the barrier of Pleasanton Ridge is due in part to a fault which lies at the eastern base of the ridge.

8. That there is little likelihood of the escape of these stored waters to the north by way of San Ramon Valley.

9. That the northern half of Sunol Valley is a smaller basin similarly occupied by water-bearing gravels to a sufficient depth to warrant its being regarded as a reserve supply.

Having stated my conclusions in summary form in so far as they agree with those of Professor Branner as to the question of most interest to you, I may now proceed to indicate something of the observations and reasoning upon which these conclusions and others are based.

To clear the way for this it will be first necessary to make a brief general statement regarding the geological formations with which we are concerned.

The General Geology.

The oldest rocks are those of the Franciscan series. These are partly sedimentary, partly igneous and partly metamorphic. They are the hardest and most resistant rocks of the region. Pebbles derived from them are common in all the conglomerates of later sedimentary formations and these are usually easily recognizable as fragments of Franciscan rocks.

The Franciscan rocks were uplifted, folded and faulted, greatly eroded and then the eroded surface was depressed below the sea and upon this sea floor there accumulated a great thickness of cretaceous sediments comprising sandstone, slates and conglomerate, known as the Shasta-Chico series. The Eocene and Miocene formations are represented in the region, but do not appear in the territory with which we are immediately concerned. The next group of rocks is the San Pablo group. This consists of marine Tertiary sediments of early Pliocene age, which were deposited unconformable upon the worn surface of the Franciscan and Shasta-Chico series. The region was again disturbed and again subjected to erosion. The erosional surface thus established was then depressed but not sufficiently to admit the sea, and in the basin thus formed accumulated a great thickness of lacustrine and fluviatile deposits known as the Orindan formation. These are the Pliocene gravels of Professor Branner's report.

The Pliocene gravels of Professor Branner's report appear to me to be a southerly extension of the fresh water beds which are extensively developed in the hills between Berkeley and Mt. Diablo, and which were some years ago described by me and named the Orindan formation. These beds have an aggregate thickness of several thousand feet and comprise not only thick strata of gravel which are evidently fluviatile in origin, but also strata of clay, limestone, and sandstone, all containing fresh water fossils which were evidently deposited in a lake. Besides these there are occasional beds of volcanic ashes or tuff. It is clear from the fact that flood plain and delta gravels occur at several horizons in the Orindan formation that the basin in which these deposits

were accumulating filled up from time to time, since such gravels could not have been spread out in deep water. It is also clear that since the formation aggregates several thousand feet in thickness that the basin in which they were accumulating was subject to progressive subsidence during the course of that accumulation. That is to say, the Orindan formation accumulated in a geosynclinal trough which was in course of development in late Pliocene time and which served as a trap to intercept the erosional waste of the adjacent uplands in its normal path to the sea, just as the Great Valley of California is today intercepting the erosional waste of the Sierra Nevada and so causing an extensive deposit of fresh water beds in that depression.

It is further evident from these conditions that the development of the trough or basin in which the Orindan beds were accumulating involved a slight deformation not only of the pre-Orindan surface, but also of the lower beds of the Orindan formation itself before the completion of the Orindan deposition. The character of the Orindan beds is naturally not constant over the extent of the formation. The lower beds are coarser and more gravelly than the upper beds. In those portions of Orindan time when the basin had temporarily filled up, the flood plain gravels would be spread far and wide, and such stages of the accumulation are represented by more or less persistent sheets of gravel. At another stage when, in consequence of excessive subsidence, the basin was occupied by a lake, the deposition of gravel would be confined to the margins of the lake where deltas of inflowing streams were being built up. This condition is represented by locally thick beds of coarse gravel which are not persistent for great distances.

After this process of subsidence and consequent infilling had produced a deposit of several thousand feet of lacustral and fluviatile sediments, the region was affected by the acute disturbances which characterized the close of the Tertiary in this region, and the Orindan beds were folded, faulted and uplifted into the zone of erosion. Owing to their softness and lack of coherence in comparison with the older rocks of the region, the Orindan beds have been exceptionally susceptible to the attack of erosional forces except in portions of the region where they have been protected by sheets of lava which at certain centers of post-Orindan volcanic activity were poured out upon these beds and so served to protect them. These protecting areas of lava are, however, not extensive, and owing to the prevailing softness of the Orindan beds the widest and longest valleys of this portion of the Coast Ranges have been carved out of them by erosion.

Livermore Valley is one of these.

Extent of Orindan Formation.

The western boundary of the Orindan formation from Hacienda station on the Western Pacific railway to the vicinity of Dublin is the eastern base of Pleasanton Ridge, but for the greater part of this distance the boundary is concealed by later fluviatile deposits which cover the floor of Livermore Valley. To the north of Dublin the area occupied by the Orindan beds is divided by a belt of Older Tertiary rocks occurring in Las Trampas Ridge. The portion which lies to the east of Las Trampas Ridge extends from Livermore Valley northwestward, gradually passing into a well defined overturned syncline, the axial plane of which dips down to the northeast toward Mt. Diablo. The end of this syncline spoons out a little beyond the town of Walnut Creek.

The southern limit of the Orindan from Sunol Valley eastward is well shown on Professor Branner's general map showing the distribution of the Pliocene (Orindan) gravels on the south side of Livermore Valley. The northeastern boundary lies along the lower southwest flank of Mt. Diablo where the Orindan beds pass beneath the San Pablo formation with an inverted dip.

That portion of the Orindan formation which lies north of Livermore Valley is practically continuous with the area mapped by Professor Branner on the south side of the valley on the northeast side of the Arroyo del Valle, and the beds are of the same general character, being chiefly clays, and clayey sands, with occasional and quite subordinate beds of gravel, except perhaps at the base of the section.

The portion of the Orindan which occupies the hills between the Arroyo del Valle and Sunol, extending south from Pleasanton to San Antonio Creek, as shown on Professor Bran-

ner's map, is on the other hand characterized by a great abundance of gravel in thick beds with beds of finer material of the nature of sandy clay intervening. It is evident that in this part of the Orindan basin there were recurrent delta conditions due to the influx of a considerable high grade stream from the uplands to the south. This stream dropped its load of heavier detritus on the margin of the basin as a great alluvial or gravelly cone in much the same way as the alluvial cone of San Antonio Creek in the valley of Southern California is being built up at the present time; and in the lacustral stages of the basin this cone doubtless extended out in the Orindan Lake as a delta. Whether as a fan or as a delta the detritus spread out by this stream became finer to the north and northeast and eventually passed into sandy and clayey silts. There is nothing surprising in the fact that the Orindan beds on the north side of Livermore Valley are finer grained and that the gravel beds are thinner and fewer in number than in the hills south of Pleasanton.

Origin of Valley.

The dissection and erosion of the Orindan formation which has given us Livermore Valley and other similarly wide valleys in this part of the Coast Range was induced by uplift of the region. But that uplift has not been a simple, uniform elevation, but rather a complicated, fitful and uneven buckling or warping of the earth's crust. This is apparent from the contrast of the erosional history of the two sides of Livermore Valley as revealed in the forms of the resulting slopes. On the south side of the valley the profiles of the hills, particularly in the lower half of the slopes, are characterized by a series of well defined terraces, extending down to the floor of Livermore Valley on the one side and to San Antonio Creek on the other. These terraces were once the flood plains of streams which for each particular terrace had attained to base level and remained at base level long enough for the evolution of a broad valley floor. This indicates that in the course of the uplift of the region there were stages of repose, each represented by a terrace on which the stream evinced no tendency to vertical corrasion; and that these stages of repose were succeeded by a renewal of the uplift which caused the stream to cut down to a lower level where after finding base level it carved a lower flood plain. These terraces or flood plain remnants were all heavily veneered with gravel due to the meandering of the stream and its tendency to aggrade as the flood plain became more extended. This veneer of gravel upon the terraces is liable to give the impression that the Orindan formation out of which the terraces have been cut is more gravelly than it really is; and this impression must be guarded against in any attempt to judge of the amount of gravel present in the make-up of the hills. Now this terracing which is so marked a feature of the hills south of Livermore Valley is not observable in the hills on the north side of the valley. The conditions of erosion here appear to have been those of completed uplift rather than those of uplift by stages.

Nature of Valley Fill.

In contrast with the evidence of uplift of two different kinds on the two sides of Livermore Valley, the valley itself has suffered depression. The process now in progress on the floor of Livermore Valley is one of aggradation in contrast to the degradation which is going on in the surrounding hills. The valley is filling up with product of the degradation of the hills. The material which is swept into the valley in the rainy season is added to the surface in successive layers so that the floor of the valley is gradually rising. That this process is in active operation is impressively shown by the fact that the older fences in some parts of the valley are now buried in the accumulating sediment. In the distribution of this alluvial filling there is a distinct sorting of materials. The coarse gravels brought down notably by the Arroyo Mocho and the Arroyo del Valle are dropped by the streams as soon as the latter begin to spread out on the valley floor and thus tend to accumulate in the southeastern part of the valley; while the finer sands and clays are carried forward by the floods and tend to accumulate in the western part of the valley floor. But at an earlier stage of this infilling of the valley, before the grade of the streams had become flattened by the process of infilling, the gravels were carried down on the flood plain to the very west end of the val-

ley. Owing to the filling up of the valley the grades of both the Arroyo Mocho and the Arroyo del Valle have become so flat that the gravels cannot now be carried so far, and the gravels which were brought down to the west end of the valley in former times are now buried by forty feet or more of fine clayey silt. For the purpose of distinguishing these deposits, which thus fill Livermore Valley up to its present floor, from the older Orindan deposits upon which they rest, I shall refer to them as the Livermore formation. In considering the distribution of the underground water of Livermore Valley we shall have to give attention to the gravels of both the Orindan and Livermore formations.

Drainage Line of Arroyo Mocho and Arroyo del Valle Diverted to South.

Now before the depression which inaugurated the deposition of the Livermore formation and the consequent infilling of the valley, the latter had been cut down to a valley floor now buried. This valley floor was carved out of the Orindan beds and the outlet of the valley during the time of its formation by erosion was probably northward by way of San Ramon Valley to Suisun Bay. This valley though now occupied by a very small and insignificant stream, is the former drainage line of the confluent Arroyo Mocho and Arroyo del Valle, and is the result of the erosion by that drainage.

In consequence of the warping of the region, a small tributary of Alameda Creek, cutting back from Sunol along a line of structural weakness has been enabled to capture the drainage of Livermore Valley and carry it to the south through the Arroyo de la Laguna. The upbuilding of the alluvial fan of Bollinger Creek at San Ramon perhaps contributed to this diversion of the drainage from San Ramon Valley to Alameda Creek; but in my opinion this was an unimportant factor. The fact that the Arroyo de la Laguna is now trenching the upbuilt alluvial plain of the lower end of Livermore Valley and that this plain extends as far as Verona indicates that the diversion of the drainage may have been a comparatively recent event and may have occurred only after the infilling of the valley had lifted the flood waters so as to enable them to pass over a low divide in soft material in the pass near Verona. It may be pointed out in this connection that movements on the Sunol-Calaveras fault mapped and described by Professor Branner may have contributed to this diversion of the drainage by creating a zone of weakness in the pass near Verona which might be readily cut into by the Arroyo de la Laguna in the northward progress of its head water erosion.

Formations Like Fill of Livermore Valley Practically Unknown in Eastern United States.

Thus far I have outlined the general geological history of the region about Livermore Valley and we may now review the facts and see what their significance is from the point of view of underground water. In doing this we may with advantage consider the Livermore formation which occupies the valley carved out of the Orindan beds. **This formation although abruptly terminated toward the west by abutment upon the base of Pleasanton Ridge is nevertheless of the nature of an alluvial fan or zone. Such alluvial fans are characteristically the natural underground storage reservoirs of vast supplies of water. They are peculiar features of the western part of the country and they are practically unknown in the eastern United States. They occur in many parts of California and other western states usually where a narrow high grade canyon opens abruptly upon a wide valley in which flows a comparatively low grade stream.** This relationship of narrow torrential canyon entering large valleys transversely is usually due to the fact the large valley owes its existence to geologically recent movements, such as faulting, which have allowed the ground under the valley to be depressed and so give rise to a large structural trough, whereas the narrow canons which emerge upon it from the mountains, which bound it owe their existence wholly to the erosion of the stream itself. The same relationship may, however, be also due in other cases to the presence of very soft formations adjacent to hard resistant rocks. The soft rocks are rapidly removed by erosion and a wide valley may be formed, but the same streams which are able to evolve a large feature in the soft formations may have been competent to cut only a narrow canon in the nearby hard

and resistant rocks. In this way we would have gradually developed a system of drainage involving narrow high grade streams flowing into a wide valley. This, as I have already pointed out, is the case in regard to Livermore Valley. Now in either case when the narrowly confined torrential stream reaches the broad valley with its load of detritus it tends to spread out and so lose velocity. The immediate result of this is that part of the load of detritus which the stream is carrying, consisting of the boulders, cobble stones and pebbles, can be carried no farther. They come to rest and pile up as an embankment in front of the mouth of the canon. The sand is carried further down and the clay still farther. This recurs each rainy season and eventually the embankment grows so high that the stream running over it is in an unstable position and takes a short cut down the slope of the embankment to lower ground on one side or the other. Here the piling up of coarse detritus takes place and the stream is once more caused to change its path. This recurs over and over again, but all the various courses taken by the stream in its many shifts are radial from the mouth of the narrow canon. The channel of the stream at any given time is gravelly far down the slope of the fan and in times of flood, when the water spreads out over the entire slope the fine silts are deposited over the previous gravelly channel. In this way every channel is not only built up into an elongated lens or ridge of gravel extending far down into the valley, but every such lens or ridge is sooner or later buried by fine clayey silt and so sealed; and every such sealed lenticular ridge is in direct connection with the apical dump of coarse gravel. The net result as the process becomes advanced is that there is a radial system of cylinder lenses of gravel radiating in all directions outward from the apex of the fan, diverging in the vertical sense as well as in the horizontal, sometimes interconnected and sometimes not, and all below a certain level in the upper part of the fan imbedded in impervious clay. In the state of nature these cylinder lenses of gravel remain saturated with water up to the level of the upper edge of the outermost cover of clay. Above this edge the water drains out of the gravels during the dry season. Below this it is permanently sealed. But if far down the slope of the fan a series of wells be bored so that the gravel channels are tapped the water will rise as an artesian flow, the head of which will be determined at first by the level of the clay edge. But if a heavy draft be made upon this stored water, then the water plane in the gravels will be lowered below the clay edge and the head of the artesian flow will be correspondingly diminished. And of course the water plane may be lowered so far that the water in the wells will not rise to the surface but will have to be lifted. This is precisely the condition that we have in the Livermore Valley.

Gravels Will Store Twelve Billion Gallons of Water.

The deposits which I have called the Livermore formation are nothing more than the combined alluvial fan of the Arroyo del Valle and the Arroyo Mocho. In the lower part of the valley there is below the surface a plexus of gravel channels sealed in clay. These gravel channels are full of water. Their capacity is very great. At the present time I would not venture to estimate that capacity satisfactorily in figures, as that would take more time than I have at my disposal involving an elaborate compilation of data much of which is insufficient for the purpose. Such an estimate would moreover fall rather within the province of the engineer more familiar with all the details of the field than I am. But on an assumption that the gravel aggregates an average of 30 feet in thickness under an area of eight square miles and that it holds 25 per cent of its volume of water, these being conservative assumptions, the gravels would store over 12 billion gallons of water. Such an estimate to be reliable, however, should be checked up by a series of wells so distributed as to limit the area occupied by the gravels and at the same time give us a better basis for computing their average thickness. The estimate is intended merely as a suggestion of the probable capacity of these gravels. The estimate, such as it is, applies only to those gravels which I can confidently refer to as the Livermore formation. There may, however, be still deeper gravels belonging to the Livermore formation which, with our present knowledge, cannot be discriminated with certainty from

the underlying gravels of the Orindan formation.

Water Storage Nearly Stationary and Constant.

The large supply of water thus stored in the Livermore gravels remains in the natural condition nearly stationary and constant. During the rainy season, particularly in winters of heavy precipitation, the gravels become filled to overflowing. They can hold no more, and the surplus runs over the gravelly intake portion of the fans and floods the lower part of the valley. Under these conditions, the water table of the lower part of the valley is above the surface of the ground. The pressure in the gravels below the clay mantle is sufficient in many places to break through the latter so that we have a natural artesian escape. The waters which flood the lower end of the valley come not only down the surface of the valley past the upper edge of the clay cover, but also through the gravels and up through these natural artesian vents. In this way the water of the flooded surface is in direct continuity with water contained in the buried gravels. When the flood subsides the water gradient, of course, falls to a point at first determined by the level of the edge of the clay cover between Livermore and Pleasanton and then to lower positions determined by the draft made upon the gravels at the lower end of the valley. But even with the heaviest draft that has thus far been made upon these gravels, the water gradient has fallen but a few feet and has never reached the gravels themselves in the lower part of the valley. These always remain full and under a head which causes the water to rise well up into the overlying clay cover. The effect of even the heaviest draft that has yet been made upon this reservoir is to lower the level of the water in the gravels near the intake and so cause the gradient to fall a very moderate amount, leaving the great body of the gravels constantly full of water.

Regulation of Floods Will Contribute to Economic Control of Water.

It is clear from these facts that if the replenishment of the gravels at their intake could be regulated, so that a much larger proportion of the normal annual run-off of the Arroyo del Valle and the Arroyo Mocho could be caused to enter the gravels at their intake instead of running off in floods, then the draft upon the gravels at the lower end of the valley could be very greatly increased. In fact, as I see it, the only way to make use of the largest possible proportion of the available waters coming into Livermore Valley, is to force the draft on the gravels at the lower end of the valley so as to keep the water gradient permanently low. The effect of this will be to keep the gravels at the intake from being gorged with water. They will always be in a receptive condition to absorb the waters that come to them. Of course in times of extreme heavy flood the water would still rush over the intake, but this loss would be greatly minimized. The restraint of the floods by dams in the canons of the Arroyo del Valle and the Arroyo Mocho would greatly contribute to this economic control of the water. Such reservoirs of the flood waters could be drained out steadily during the summer months so as to flow into the sinks of the two streams between Livermore and Pleasanton and thus regularly replenish the gravels which are at the same time being drawn upon at the lower end of the valley. In this scheme of regulated replenishment at the intake of the gravels and forced draft at the lower end of the valley, the gravels become merely a filter on a large scale. If the floods of winter can be wholly controlled, and that is for engineers to say, then the whole of the waters of the Arroyo del Valle and the Arroyo Mocho can be made to pass into the gravels if the draft at the lower end of the valley can be made sufficiently heavy to keep the water gradient at a permanently low level. From this point of view, and assuming that the flood waters of the Arroyo del Valle and Arroyo Mocho can be wholly controlled, then the problem of the available water supply obtainable from Livermore Valley may be reduced to very simple terms. Those terms are that all the run-off of the two streams, or the waters that they bring to the valley may be filtered through the gravels of the Livermore formation and completely utilized at the lower end of the valley.

Estimated Supply From Livermore Gravels 75 M. G. D.

Estimating the hydrographic basin of the Arroyo del Valle and the Arroyo Mocho as 200

square miles and the annual run-off from this area as 8 inches of the total rainfall, the supply available figures out about 75 million gallons daily. This is of course a theoretical value and must be discounted for the exceptionally dry winter, but on the average it is not far from the truth. It has at least this value, that it is an expression for the limits of the supply and good engineering will undoubtedly in the course of years work up gradually and eventually very closely to this limit.

Conclusions Reached Independent of Water Bearing Capacity of Orindan Gravels.

Now you will observe that this discussion and the conclusions reached are quite independent of any consideration of the water bearing capacity of the Orindan gravels. I have shown that the Livermore gravels occupy the floor of a valley carved out of the Orindan. In the Orindan of the hills south of Pleasanton there are thick beds of feebly cemented gravel, and these undoubtedly pass under the Livermore gravels across the floor of the valley in which the latter lie. In other words, the Livermore gravels lie unconformably upon the worn edges of various horizons of the more or less inclined Orindan formation. It results from this that the Orindan gravels below Livermore Valley and also those below the hills south of Pleasanton up to the level of the water table of Livermore Valley are saturated with water to an unknown but very great depth—several hundred feet at least. In one point of view these Orindan gravels constitute a very large underground storage of water in addition to the storage capacity of the Livermore gravels. But I do not see that they contribute anything to the available supply since from the foregoing discussion it must be apparent that such supply is limited absolutely by the inflow to Livermore Valley, and this for practical purposes is measured by the discharge of the canons of the Arroyo del Valle and the Arroyo Mocho. The outcropping edges of these Orindan gravels do, to be sure, afford additional intake facilities feeding the underground reservoir; and the continuity of these gravels from the floor of Livermore Valley through the hills to Sunol Valley may be of importance from an engineering point of view in the practical exploitation of the supply, but the existence of this deeper reservoir in the Orindan formation can never add to the available total supply from this general basin. It might, however, be drawn upon by heavy pumping in times of emergency such, for example, as an earthquake disaster affecting adversely the galleries at the lower end of Livermore Valley. It is of course of interest to know that there is a large, deep reservoir of underground water below the Livermore gravels and should it turn out, contrary to my present expectation, that it is desirable to exploit this reserve I should be happy to give further consideration to the matter.

Sunol Valley.

Sunol Valley is veneered with the flood plain gravels of Alameda Creek, but the Orindan gravels which lie to the north of Sunol as well as those exposed in the stream cliff south of the town dip in a general southeasterly direction beneath the valley floor. It, therefore, appears extremely probable that there is a considerable body of Orindan gravel below the valley and that these would have a greater depth toward the east side than elsewhere. These gravels are probably in thick strata separated by sandy clay, and it may be necessary to go through one or more beds of this sandy clay before reaching the main body of the gravel. I am not quite clear as to how this water in the gravels below Sunol Valley could be exploited without interfering with the existing filtering plant, as I am not familiar with the details of that plant. As I have already pointed out, the Orindan gravels are probably continuous from Sunol Valley through the hills to Livermore Valley, and a heavy draft on the Sunol portion of the Orindan underground reservoir would doubtless affect the water gradient at the lower end of the Livermore valley.

Yours sincerely,

ANDREW C. LAWSON.

PROF. BRANNER AND PROF. LAWSON IN ACCORD ON THE CONCLUSION THAT LIVERMORE VALLEY IS A GREAT STORAGE BASIN, CAPABLE OF ENORMOUS DEVELOPMENT

Leland Stanford Junior University.

Office of the Vice-President.

Stanford University, Cal., June 3, 1912.

S. P. Eastman, Esq., Spring Valley Water Company, San Francisco, Cal.

Dear Sir:

Dr. A. C. Lawson has kindly sent me, with your approval, a copy of his report made to you on the underground water conditions of the Livermore Valley and dated May 31, 1912.

In view of Professor Lawson's conclusions, it does not seem necessary for me to do more than to call your attention to the fact, mentioned by Professor Lawson himself, that in so far as the Spring Valley Water Company's interests are concerned, we are substantially in accord.

I regard this agreement upon the main facts as of the greatest importance to the company, for it suggests, if it does not prove, that however geologists may approach the problems involved, whether the gravels have been let down by faulting or by folding, the inevitable conclusion is that the Livermore Valley is a great storage basin of unusual and remarkable structure, and capable of enormous development.

Very truly yours,

J. C. BRANNER.

ERRONEOUS GEOLOGICAL CONCLUSIONS ON FORMATION OF LIVERMORE VALLEY ADOPTED IN FREEMAN REPORT

BY

Dr. J. C. Branner,
Geologist.

Stanford University, Cal., Oct. 4, 1912.

S. P. Eastman, Esq.,
Manager, Spring Valley Water Company,
San Francisco, Cal.

Dear Sir:—This is in reply to the memoranda sent me in regard to geological points mentioned in Mr. John R. Freeman's report to the Mayor and City Attorney of the City of San Francisco on the Hetch Hetchy water supply.

The page numbers here used refer to the pages of Mr. Freeman's printed report bearing date of July 15, 1912.

At pages 190-191 Mr. Freeman appears to accept without question the correlations made of the gravel and other beds in the Livermore Valley region by Mr. C. Williams, and at pages 200-201 he even regards my statements as confirming the statements and conclusions of Mr. Williams.

I have already stated in my letter of July 3d, 1912, and I here reaffirm my conviction that my experience of such deposits leads me to conclude that most of the geologic correlations made by Mr. Williams in his report on the Livermore Valley are not only not to be trusted, but that they are a source of serious weakness in all the conclusions based upon them.* I myself attempted to make such correlations, using the well logs over the same region. In order to leave as little as possible to the imagination, my sections, in place of having an exaggerated vertical scale, were platted to the same horizontal and vertical scales.

I found that where the wells are only a short distance apart trustworthy correlations are possible, but as the distance apart of the wells increases, correlations not only become worthless, but they are liable to be entirely misleading.

The sections given at pages 89 and 90 illustrate what I mean. In one group near the pumping station west of Pleasanton the wells are only 50 feet apart, and the materials passed through can be identified readily and correlated with reasonable certainty. But it is one thing to correlate a gravel bed by means of well logs 50 feet apart; it is quite another matter to correlate beds over a distance of three thousand feet without intervening wells to support the correlation. At page 90 such correlations are made repeatedly.

The streams in which these gravels were laid down were little if any larger than the Arroyo del Valle of to-day, and only occasionally are the gravel deposits of that stream more than a couple of hundred feet wide. To be sure, the gravel deposits might be identified with greater certainty over longer distances if we could study them along the axes of the streams, but unfortunately we cannot be sure of the axes of the ancient streams, owing to their meanders.

So far, therefore, as this is a geological problem, I feel that Messrs. Schussler, Mulholland and Grunsky wisely omitted to make the correlations undertaken by Mr. Williams and commended by Mr. Freeman at pages 190 and 193.

At page 191 it is said that some exposed beds classed as gravel by me were inspected by Mr. Freeman's assistant, who found them nearly impervious as regards practical water supply. The statement is quite correct as it stands, but it is

*The conclusions of Mr. Freeman are based upon these geological sections.

also quite misleading. The gravel beds referred to in this statement are the older Pliocene gravels, sands, and clays that underlie the whole or nearly all of the valley, and are described in my report to you under date of May 6, 1912.

It is a feature of such deposits that the porous beds invariably break down under weathering agencies, while the more impervious ones resist and form the natural outcrops.

If one examines the outcrops of the water-bearing deposits of the Santa Clara Valley, he finds the exposed beds almost invariably apparently water-tight. But wells put down in this same series of beds find abundant water.

Another point in regard to beds that appear on their outcrops to be impervious is that it not infrequently happens that they are impervious on account of oxidation and alteration of the materials when they have been long exposed to weathering, while the same beds, under deep cover, may be quite porous. An interesting case illustrating this fact occurred here at Stanford University some years ago: An excavation was made for an artificial lake in a bed of Pliocene gravels that appeared on the outcrops to be quite impervious. When the work was done and the water was turned into the basin, it ran out about as fast as it ran in, while the water in wells about Menlo Park, two miles away, rose considerably above the usual level.

These and many other illustrations that I might cite lead me to infer that the Pliocene beds south of Pleasanton may reasonably be regarded as water-bearing until the contrary is shown to be the case. As a matter of fact, there are at least two artesian wells near Pleasanton receiving their waters from these Pliocene beds, and you are quite right in thinking that I regard them as conclusive evidence that these gravels will yield water; and I think that any geologist would agree with me.

At page 197 it is stated that the foundation of the Sunol gallery rests on an impervious bottom.

Everything I know of the geology of that valley leads me to infer that the bulk of it is filled with gravels, sands, and clays to a depth of several hundred feet. The exact depth, however, cannot be predicted with certainty, owing to the presence of local faults; but inasmuch as most of the valley is carved in the hard black Cretaceous shales that are well exposed through the Niles canyon, there can be no doubt about the bed rock when that is reached, for it is of materials entirely different from the filled-in materials.

Very truly yours,

J. C. BRANNER,
Consulting Geologist.

A REVIEW OF CERTAIN CONCLUSIONS PRESENTED BY MR. JOHN R. FREEMAN ON THE DEPENDABLE YIELD OF THE ALAMEDA SYSTEM OF THE SPRING VALLEY WATER COMPANY

BY

WM. MULHOLLAND.
Chief Engineer Los Angeles Aqueduct,

AND

J. B. LIPPINCOTT,
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There has been presented to the Board of Army Engineers, as requested by the Secretary of the Interior, a number of reports dealing with the resources of the Spring Valley Water Company, of which one report by Mr. F. C. Herrmann, Chief Engineer of the Spring Valley Water Company, fully discusses the available water supply owned and controlled by the Company.

Thorough Studies Made of Alameda System.

Mr. Herrmann was born and raised at San Jose and received his engineering training at Berkeley, all practically in the district under discussion. His professional work has included official water supply investigations for the federal government, and responsible charge of extensive hydraulic works. He is surrounded by a corps of engineers, some of whom have spent years of study and observation of the Spring Valley system. To assist this regular engineering organization, he has called in consultation Dr. J. C. Branner, Vice-President of Stanford University, and Dr. A. C. Lawson, Professor of Geology of the University of California, both eminent geologists, especially familiar with the bay regions through years of geological study thereof. He also has had in consultation the engineering staff of J. G. White and Company, Mr. George G. Anderson, an eminent engineer of Denver, Captain A. O. Powell, C. E. of Seattle, and General Hiram M. Chittenden, retired, of the corps of engineers of the United States Army. General Chittenden has specialized for years on the hydrography of arid America. All of these gentlemen, together with ourselves, have gone over the districts under discussion in the reports, in detail with Mr. Herrmann and have conferred with him both in the field and in the office. The deliberations have been extensive and a mass of data has been compiled by Mr. Herrmann and his assistants which is presented in their reports. It therefore follows that the conclusions reached by Mr. Herrmann are worthy of respectful consideration and should be given weight in reaching final judgment.

Mr. Herrmann has presented a report which is a clear and concise review of much detailed matter contained in seven appendices and many maps and diagrams which are referred to therein. It is not in the nature of a report produced under high pressure in the short period of two or three months' time by one who is a non-resident and but briefly familiar with Pacific Coast conditions, and the ordinary sources of our domestic water supplies, covering one-third of the second largest state in the Union, involving estimates of construction

cost running into staggering figures and unprecedented plans, but is rather the findings of men who have made good in their life work in this particular locality.

Livermore Valley Gravels.

It is the conclusion of Mr. Herrmann that the Livermore Valley gravels are good for a safe yield of 55.38 M. G. D. of pure water, when the Arroyo Valle reservoir, the site for which the Company owns, is constructed. The figures are based upon mass curve studies of the capacity of the Arroyo Valle reservoir to regulate the flood waters of that stream to such an extent that the gravels of the lower valley can absorb them, as determined by actual observations on that stream itself. He has determined the capacity of the Livermore gravels by a survey of their surface area, a collection of well logs, geologic studies and field determinations of the void content of the aggregates. In turn a mass study has been made of the hypothetical status of this underground reservoir during the period of the last 23 years, during which gagings have been made on the lower reaches of Alameda Creek, and five years' Arroyo Valle gagings. His deductions are clear and logical.

Calaveras and Upper Alameda Streams.

Mr. Herrmann has made a similar study of the supply available from the Calaveras and upper Alameda streams, the reservoir sites and much of the watershed of which the Company owns. Studies of run-off have been made, based upon the observed flow at Niles and Sunol during the 23-year period and 12 years' stream record at Calaveras. A mass curve has been drawn for a dam and reservoir capacity as recommended to the Company for the Calaveras site by Mr. Freeman of 55,000 M. G. capacity. Due allowance is made by Mr. Herrmann for evaporation and surplus from the reservoir and he concludes there is a safe available supply therefrom of 60.14 M. G. D. This water will come from a high mountainous catchment area of 133.62 square miles, almost devoid of occupation and the quality of the water is unquestioned. Mr. Freeman recommends the construction of this dam, both to the Company and to the City of San Francisco.

San Antonio and Sunol.

On the San Antonio branch of Alameda Creek is another reservoir site, which the Company owns, of 11,674 M. G. capacity, with a tributary catchment area of 38.7 square miles of mountains. Mr. Herrmann in a similar way has computed its safe yield at 8.92 M. G. D. To secure the position of the Company against adverse claimants, both physically and legally, it has purchased 37,000 acres in and surrounding them, together with the 14,600 acres of riparian lands along the streams to tide water in San Francisco Bay. This is in addition to purchases in Livermore Valley by the Company. The holdings of the Company in the Alameda System aggregate over 55,000 acres.

There are 49.08 square miles of drainage area, ranging from 200 to 3,800 feet in elevation, that is not controlled by any of the regulations above referred to. This is tributary to the Sunol gravels, which are 1,300 acres in area, all owned by the Company and with a known depth of 200 feet and an estimated storage capacity of at least 10,000 M. G. for an average depth of 100 feet. The surplus waters from the Calaveras and the San Antonio will also pass over this gravel bed, the efficiency of which is already established by the Company's filtration galleries. Other waters escaping from Livermore Valley can be cheaply diverted onto this area.

By the use of wells and pumps to an average depth of 100 feet Mr. Herrmann estimates that the Sunol gravels may be relied upon to produce 11.36 M. G. D. of water of good quality.

The following conclusion is reached as to the total available safe yield from the Alameda Creek System, with its 620.5 square miles of area:

DEPENDABLE SAFE YIELD FROM THE ALAMEDA SYSTEM.

	M. G. D.
Calaveras and Upper Alameda	60.14
San Antonio	8.92
Sunol Gravels	11.36
Arroyo Valle Reservoir and Livermore Gravels	55.38
Total	135.80

The estimated average gross water crop from this entire basin, including evaporation and wastes, is given as 173.39 M. G. D. for the 23-year period for which gagings are available, of which the 135.80 M. G. D. may be conserved. The

Company is now obtaining but 16 M. G. D. from this source and is holding the available balance for the future necessities of the City of San Francisco, exclusive of the streams on the coast side of the Peninsula. Even if the claims of the Niles Cone must be recognized to the extent that Mr. Freeman suggests (30 M. G. D.), which is not here admitted, there remains an available supply from Alameda Creek alone, the quality of which cannot be questioned, equal to three times the present consumption of the City of San Francisco. This supply is large enough to at least relieve the apprehension of the present generation. In addition, Mr. Herrmann estimates the supply that may be obtained from Peninsular streams on the western or ocean slope, on which the Water Company owns riparian rights, as 51.2 M. G. D. This is a region of heavy precipitation, of practically no agricultural possibilities, the water crop from which wastes directly into the ocean.

COMMENTS ON MR. FREEMAN'S REPORT.

The purpose in writing our reports of February and July, 1912, concerning the available water supply in the Livermore Valley, was with the hope of assisting the Spring Valley Water Company, and through it the City of San Francisco, to meet the increased demands owing to the rapid growth of the city, and particularly to meet extraordinary demands for water anticipated by the Panama-Pacific Exposition.

Our report of February, 1912, was made in response to inquiries of the Spring Valley Water Company, it having in contemplation extensive purchases of additional property in the Livermore Valley and was for the purpose of expressing our views in regard to the prospect of developments in addition to those already in use by the Spring Valley Water Company. Pursuant to that report the Company subsequently made extensive purchases, partly on the basis of the conclusions of our report.

Mr. John R. Freeman, consulting engineer for the City, finds in his report of July 15, 1912 (p. 97), that "As a whole, the additional quantity available from all the sources owned by the Spring Valley Water Company is probably no more than sufficient to supply the increasing demand until the Hetch Hetchy works could be completed, if begun within the next three years."

Productivity of Livermore Valley 50 Million Gallons Daily.

The fact that we consider it possible to obtain about 50 M. G. D. in the Livermore Valley, as we have done in the valley of the Los Angeles River, was not and is not considered by ourselves as an objection or opposition to the granting of rights of way to the City of San Francisco for the Hetch Hetchy aqueduct. We are not antagonistic to the Hetch Hetchy project for the ultimate needs of the communities around San Francisco Bay. We believe that it would be just as unnecessary and just as unfair for the engineers and officers of the Spring Valley Company to oppose the granting of these rights to San Francisco and her affiliated cities, as it is for the representatives of San Francisco to belittle the local available water supplies which are now required by the City and which we believe to exist in the basin of Alameda Creek, and for them to build up such a public sentiment and array of alleged physical facts as will tend to incite opposition, bitterness and litigation against the Spring Valley Water Company, or its successors, in its efforts to meet the necessities of the City.

Spring Valley Water Company Not Antagonistic to Sierra Supply.

Nothing has been said in any of the reports which we have seen by any of the representatives of the Spring Valley Company in opposition to the City's claims for a Sierra water supply. The Secretary of the Interior, however, has specifically requested the Spring Valley Water Company to file a statement with the Department, showing the extent of the local water supply and of their water systems, and they naturally and properly object to having properties that they have been cherishing and developing for a generation and upon which they have spent millions of money, unfairly belittled.

As engineers of the Los Angeles aqueduct, we have taken pleasure in freely placing before the numerous investigators, representing the City of San Francisco, all the data and statistics that were available, showing the cost of the construction of the Los Angeles aqueduct, as a

guide in making estimates for the Hetch Hetchy project. This data has been accepted, used and published by them. We feel an interest in seeing successful completion of this great enterprise, which we believe in part to have been stimulated by the energies of our city. Yet when we asked for conferences with Mr. Freeman at which we could discuss the differences which had arisen between us relative to physical facts in the basin of Alameda Creek we were surprised at being denied this privilege, and we are equally astonished that our reports and estimates on the Livermore Valley, which also were presented to him, have been made the subject of practically a hostile attack, in view of the fact that we believe that these local supplies are necessary and valuable for the health and safety of the metropolitan community.

Mr. Freeman in Position of Trader.

On page 194, Mr. Freeman states that in estimating the available water supply from Alameda Creek "the buyer should have the benefit of doubts." He considers in his report that every doubtful question, *and apparently in every question involving judgment,* all the decisions should be cast against the Spring Valley Water Company. This is very apparent in reading his report. Mr. Freeman places himself in the position of a trader who wishes to get the best possible price for his client and assumes that the way to accomplish this is to depreciate the property. He says on page 190: "In the purchase of a mine, or of anything where the element of value has dimly defined boundaries, it is the general principle of business to construe the doubt mainly in favor of the purchaser, and it is invariably the rule of conservative engineers to decide the doubtful points on the side of safety when planning a domestic water supply." In his reports on the water supply for the City of Brooklyn, quoted in detail by Mr. Herrmann, it is stated that the underground sources of water supply may be determined there with certainty. This course may possibly be good trading, but it is not judicial, nor is it scientific reporting. These reports should be a presentation of facts to a board of engineers. Possibly he considers this trading attitude justified by the fact that the City is now negotiating for the purchase of the property of the Spring Valley Water Company, and also that he desires to show a dire necessity on the part of this community, in his application to the Secretary of the Interior. This, however, has nothing to do with an application for a right of way over public lands. In case of the purchase of this property by the City it is feared that the report which Mr. Freeman has written will be the cause of grave embarrassment to the municipality in the development which he considers necessary in the Alameda Creek basin.

Prejudicial Attitude Shown in Constant Reference to Alleged Legal Difficulties of Spring Valley Supply.

The prejudicial attitude which Mr. Freeman has taken (page 94) is indicated by his persistent reference to the legal difficulty of depriving the lands of Niles Cone of their water supply, and yet (on p. 175) he states that while the total output from this cone is 14 M. G. D., 8½ M. G. D. of this amount is being diverted for uses outside of the cone, by other domestic water companies, about 8 M. G. D. being sent to Oakland and ½ M. G. D. to Haywards, and in stating the legal inability of the Spring Valley Water Company to utilize extensively the waters of Alameda Creek he makes no reference to the fact that the Company has bought over 55,000 acres of land in that drainage basin to protect its rights; that it owns complete riparian holdings from the Livermore Valley and the Calaveras reservoir site, through to San Francisco Bay, and that it has purchased over 6,500 acres of water bearing land at a cost exceeding two million dollars, in the strategic portion of the Livermore Valley where the greatest opportunities exist for the development of the underground water, and in localities where the flood waters would naturally sink into the ground. These latter lands have a most direct and positive bearing both on the ability of the Spring Valley Water Company to withdraw water from the Valley and also as a protection against the encroachment of local users, which Mr. Freeman so fears.

No Reference Made to Possible Legal Complications of Sierra Supply.

On the other hand, we have seen no reference

in Mr. Freeman's report, to the legal complications which would arise from taking 500 million gallons daily (775 sec. ft.) from one of the most important rivers of California, away from the largest valley in the state, where irrigation is essential, and yet in its infancy, removing it from its drainage basin and using it for domestic supplies around San Francisco Bay, in the face of adverse rulings of our courts.

The City of Los Angeles considered it necessary to purchase 130,000 acres of land, including both banks of the Owens River, from the diversion point of the Los Angeles aqueduct to the mouth of the river at Owens Lake, and including many miles of riparian lands around the lake, and thousands of acres of irrigated lands, to protect its proposed diversion. The necessity for similar procedure has been recognized in the past by the Spring Valley Water Company, as may be noted from maps showing its holdings on both sides of the Bay, which indicate the completeness with which it has guarded against the attacks of lower riparian claimants.

Evaporation Losses Enlarged Upon.

Again, Mr. Freeman enlarges upon evaporation losses that will occur from storage reservoirs which may be built in the drainage basin of Alameda Creek. He places these at from 8 to 10 M. G. D. On page 199, in discussing the evaporation losses from swamp lands near Pleasanton, he considers the estimates used by us as too low. We believe these losses to be over 12 M. G. D. This is an absolute loss of no benefit whatever to the people in the Niles Cone or anywhere else. The stopping of this evaporation loss, which is proposed by us, would be a true conservation of a lost natural resource. More careful and elaborate studies than were possible for us to make have been prepared since we called attention to this subject last February. Mr. Charles A. Lee, who has made a special study of this subject for the City of Los Angeles and also for the United States Geological Survey, estimates this loss, which may be saved, at 15.7 M. G. D., and Mr. F. C. Herrmann, having studied the subject during the past summer, places it (Appendix D) at an average of 20 M. G. D. for the last 23 years, while the figure used by us was 12 M. G. D., or more. Yet Mr. Freeman gives no credit to the Spring Valley Water Company for its ability to lower the water plane by pumping and thus save this loss. This amount alone is as much as Mr. Freeman is willing to admit can be obtained in the way of an additional water supply from the entire 620 square miles of Alameda Creek, involving in his estimate one unit alone, the construction of the Calaveras Dam, at his estimated expenditure of two years in time and two and one-half millions in money. The evaporation loss is mostly occurring on lands that are now owned by the Spring Valley Water Company.

Weir Measurements at Niles and Sunol Dams not Exaggerated.

Again, in discussing the weir measurements (pp. 84-5), made at the Niles Dam, Mr. Freeman calls attention to the fact that these weir measurements indicate excessive volumes, because the head on the weir is submerged and because of eddies in the approaching stream; yet he ignores the fact that the velocity of approach to this weir would be very high, probably as great as from 10 to 15 feet per second, and that the bay above the weir being filled with gravel will prevent complete contraction of the jet. Both of these factors would tend to make the indicated flow, as computed by the Francis weir formula, too low, and, judging from observations made on models and elaborate computations made by a number of eminent engineers, these two factors more than compensate for the submergence of the weir.

The figures taken from the tables of the Spring Valley Water Company, based on Mr. Schussler's formula, which is a form of the Francis formula, and which have been used by various engineers in this discussion for the twenty-two-year period from 1889 to 1911, amount to 137.7 M. G. D. The flow for this period as computed by Mr. George G. Anderson was 158 M. G. D., and the flow computed by means of the Le Conte and Herrmann models for the Spring Valley Water Company, was 149½ M. G. D. The computations of the committee of engineers appointed at the request of Mr. Freeman, consisting of Messrs. Grunsky, Marx and Hyde, which were made for the City of San Francisco, (Page 82) have not been published by Mr. Freeman, but as he accepts Mr. Schussler's results, it is to be inferred that their computations show at least as much as Mr. Schussler's figures. Their re-

port should be presented to the Board of Army Engineers.

Coming back to the gaging at the Niles and Sunol Dams, which afford the basis from which proceeds all the discussions of the surface yield of the Alameda watersheds, it will be noticed that Mr. Freeman deduces the strange conclusion that all the conditions in which these dams depart from true weirs militate against accuracy on the side of exaggeration of the discharge and offers in support of his contention views of different stages of flow on the Sunol Dam. Two of the views, Nos. 7 and 8, show the river in moderate flood and are accompanied by the note that they were computed by the Spring Valley Water Company as for ideal weir conditions.

If this were the case and all the other flood discharges were computed likewise, without doubt the discharge has been minimized at all times when the depth over the lip of the dam exceeded two feet or probably even at a lesser depth.

In the Freeman report the view marked No. 7 is shown as a noteworthy example of the effect of the backwater presumably in retarding the velocity over the dam, whereas as a matter of fact the flat trajectory of the onrushing torrent clearly indicates a velocity far in excess of what would be induced by a four-foot depth of water over an ideal weir.

The mean velocity of overfall in an ideal weir, considering the entire notch area for a depth of four feet is about 6 2-3 feet per second and probably in the very center of the vena contracta does not exceed 7½ feet, while here we have a stream with a fall of 26 feet per mile bounding tumultuously down its course with a velocity that the most conservative stream flow formula will not place at less than 10 feet per second and supremely contemptuous of such puny obstruction as this dam offers to restrain its behavior to conform to the placid requirements of the Francis formula.

Surely this is a case where not the remotest semblance of the essential conditions for the use of this elegant and classic formula exists. The double wonder is first that this dam should be regarded as a weir, when it came to the measurement of considerable flows and secondly that Mr. Freeman with his oft repeated expressions of caution and after his evident examination of the channel in which he pronounced it, "excellently straight" should hold and express the opinion that the obstruction exaggerated the actual flow.

The catchment area of the Alameda Creek Basin is one which, from its fan-like shape and subdivision into many finger-like branches of comparatively short distance to their mountainous heads, favors the rapid delivery of floods to the common outlet at Niles Canyon, hence is it not worthy of note that the greatest recorded measurements only show by the system used in computing the discharges, 45 second feet per square mile in a region of such copious precipitation, comparatively little of which is in the form of snow, as against a discharge of over 100 second feet per square mile for the Los Angeles River, with storms of less intensity and much less favorable topography for rapid runoff.

In view of all these facts the conclusion is justified that the amount of runoff, during floods of even moderate intensity is greatly, if not grossly, minimized. Surely if the accepted measurements are correct, Alameda Creek should be awarded a medal for deportment.

Is there any logical reason to be assigned to the fact that the San Leandro watershed should yield one-fifth of a million gallons daily per square mile into Lake Chabot for storage in addition to an abundant flood flow not retained by the dam, with a less rainfall than the neighboring watershed of Alameda Creek, whose total flow is not in this voluminous report considered to be equal, flood waters and all, to half this yield?

Ultimate Use of Surface Reservoirs.

On page 187, and under the subject heading "Practical Yield Smaller than Maximum Theoretic", the statement is made—"It is widely recognized among water supply experts that it is disadvantageous to hold storage reservoirs partially empty continuously over more than from two to five years in succession, because of the growths of weeds on the exposed beds, etc." This on the authority of Stearns, Fitzgerald and other water supply engineers. If memory may be relied upon, these are the gentlemen who required the stripping of surface soil for a depth of from three to eight feet in the Wachussetts Reservoir site, and we of the West

think that with all our experience in reservoirs, we may be permitted, at least with regard to our own climatic conditions, to dissent from such heroic and expensive treatment.

Experience here has shown that areas submerged are much benefited by occasional exposure and aeration, the process tending to kill and oxidize the water organism accumulating in the bottom of the reservoir and in general sweetening the ground. The assumption that the growth of land plants over the uncovered area will not be prevented implies more than a physical change and carries with it the idea of a complete revolution in the social condition of the country, calling as it does for the utter extinction and disappearance from our social life of that much exploited character "The man with the hoe". It surely would not prove an expensive matter and does not in fact prove very expensive to keep the margins of receding lakes free from the growth of land plants, and there is nothing in the contention that reservoirs should not be drained below certain levels, as their contents should be available, when necessary, to the full extent of their capacities. It would prove an unfortunate experience for the City of Los Angeles in her Aqueduct enterprise should this theory of the complete unwatering of a reservoir be applicable to the Long Valley Reservoir site, for instance, and Mr. Freeman in his very valuable report on that project gave no hint of impending danger from this cause. It might be asked "What are reservoirs for if they are never to be emptied?"

We fail to see any merit in the proposition that a water works should not be developed to the utmost extent, especially with relation to conveniently located supplies, as it might frequently happen that the very last million gallons that might be thus obtained would have the utmost importance in tiding over the effects of some unforeseen catastrophe. This is especially true where the ultimate development involves no greater relative expenditure than that of any earlier portion of the work. The City of Los Angeles has been enabled to proceed with her present rapid development only by resorting to the very ultimate exploitation of her present water resources. Another noteworthy proof is the existing full development of the Peninsular water supply of the Spring Valley Water Co.

Underground Waters.

Among the exhibits of Mr. Freeman's report on page 89, is what purports to be a number of sectional views of the alluvial formations of the Livermore Valley by Cyril Williams, Jr. As an instance of the cavalier-like method used in interpolating between wells, attention is called to the horsetail-like mergence of the gravel beds shown at the right hand end of Plate E W 6, into a huge bed of clay.

This extraordinary formation is easily understood by anyone having knowledge of the vagaries of the average well borer's classifications of material. In Southern California astonishment is often experienced at the productive yield of some wells with but a few feet thick of gravel underlying beds of so-called clay. The phenomenon is accounted for by the fact that this material is found to be charged with water, notwithstanding a high clay content, which drizzles down freely over a broad area, when the sublying gravel is relieved by pumping. There are frequent instances within our knowledge of this condition in Southern California.

If the gravel of the valley formations was the only material that yielded water, over one-half of the productive irrigated area of Southern California would still be a sheep pasture.

It will be generally conceded that "Gravels will not give out more than they drink in", but materials other than actual clean gravels also absorb water and when gravel veins or sheets are interbedded with it, giving facility for underdraining it, the process of unwatering it is easily affected by the medium of wells, as is done on a large scale in Southern California in formations absolutely similar in character to that of the Livermore Valley. In fact it may be here stated that all the large cities and towns in Southern California except San Diego are supplied by ground water alone and not including the City of Los Angeles, their joint population aggregates nearly 300,000, and the City of Los Angeles itself, with a population of over 400,000 is supplied with what virtually is ground water, making a grand total of approximately three-quarters of a million people.

Our faith in the underground water supply is based upon years of investigation and development in Southern California on account of the limited nature of the surface streams. South

of the Tehachapi during a normal summer there is over twice as much water developed from underground sources as is or ever was diverted from surface reservoirs and streams. From extensive federal investigations we believe that the future development of the state for irrigation and domestic supplies south of San Francisco and Sacramento, will depend, to a greater extent, upon the development of underground water than from the building of storage reservoirs for the impounding of floods.

Mr. Freeman shows (Page 176) of his report that during the year 1911, 69% of the total supply of the People's Water Company used in Berkeley, Alameda and Oakland, came from underground sources. Nearly one-half of the present supply of the Spring Valley Water Company comes from underground sources from the basin of Alameda Creek. He is familiar with the fact that the entire supply of the City of Los Angeles of 45 M. G. D., which is an amount greater than the total use of the City of San Francisco, all comes from underground waters. In addition, the domestic supplies of Fresno, Stockton, San Bernardino, Redlands, Riverside, Pomona, Long Beach, Santa Ana, Pasadena and Santa Barbara all are derived completely from underground sources. For the portion of the state south of Sacramento very few communities use surface waters. Mr. Freeman has had important and extensive connection with the development of the underground water supplies for the City of Brooklyn. Mr. Herrmann quotes him as follows: "I am inclined to regard the underground water stored in the interstices of the saturated yellow gravel above the blue clay, as affording the very best of storage, ample in volume, removed from pollution and in many ways cheaper and better than the storage to be obtained from surface ponds or reservoirs." (Page 537, Report on New York Water Supply.) Consequently it is difficult to justify his statement given on page 191 of his San Francisco report that "Surface reservoirs here promise better than those underground", and that from his studies of similar problems on Long Island, for the City of New York, he doubts the feasibility of reclaiming any large amount of water here.

Good Judgment Shown by Spring Valley Water Company in Purchase of Livermore Valley Lands.

The Spring Valley Water Company has shown its entire good faith in its claims for an extensive underground supply from Alameda Creek in that it has purchased 6,000 acres of water-bearing land in the Livermore Valley at a cost of over two million dollars, and also the water-bearing lands in the Sunol Valley to the extent of 1,300 acres. By regulating the flood waters of the largest tributary to the Livermore Valley in the Arroyo Valle Reservoir, Mr. Schussler estimates that 46 M. G. D. can be obtained from that source, while Mr. George Anderson considers 48 M. G. D. available Mr. F. C. Herrmann, Chief Engineer of the Spring Valley Water Company, and his assistants, place this figure at 55.38 M. G. D. and we have determined it at a maximum of 51½ M. G. D., provided the Arroyo Valle floods are regulated. Mr. Freeman (Page 97) states that the estimates made by Mr. Schussler and ourselves are "gross exaggerations" and assigns to the Pleasanton region little or no value above the "6 M. G. D." now being developed (Page 190). The best answer on the part of the Company to this criticism is to put in the wells and the pumping plants near Pleasanton and to start actual development. This they are now doing upon the recommendation of their Chief Engineer and of ourselves. The Companies officials have the fullest confidence in the safe dependable ultimate yield of this source.

Similarity Between Livermore and San Fernando Valleys.

We are naturally continually impressed with the similarity between the Livermore and San Fernando Valleys. We have discussed this more at length in a letter which we prepared, calling attention to the development of underground water in Southern California, and to which we again call your attention. The various tributaries of the Los Angeles River discharging on to the fill of the San Fernando Valley are mostly absorbed by it, without surface storage regulation and reappear in the lower portions of the

valley in surface streams, filtration galleries and wells. While the area of the Livermore Valley above its narrows is but 406 square miles, that of the San Fernando Valley is 503 square miles, but the high mountainous portion of the Livermore Basin is 257 square miles above the Arroyo Valle Reservoir site and the Mocho, against 174 square miles of high mountains in the basin of the Los Angeles River. The foothill area of Livermore Valley is 138 square miles and of San Fernando 153 square miles. The rainfall in the basin of the Livermore Valley is greater than in the case of the San Fernando Valley, and the valley fill near Livermore is as favorable to the development of underground water. The output of ground water in the San Fernando Valley is fully 50 M. G. D. and we see no reason why that from the Livermore Valley should not be as great, especially if the major floods are regulated through the Arroyo Valle Reservoir.

Storage Capacity of Livermore Gravels.

The situation in the San Fernando Valley has been under our personal observation and study during the last twenty years, and it is sustaining the domestic requirements today of a city of over 400,000 people. What has been done in the San Fernando Valley has been done in many other localities in Southern California. These facts are unusual to the eastern engineer and consequently are difficult for him to appreciate.

Mr. Herrmann, from an extended study of the area of the valley, the logs of wells and the voids in the gravels, places the storage capacity of the underground reservoir of Livermore Valley at 87,000 M. G. D. for a depth of but 100 feet, or greater than the surface capacity of the Calaveras, San Antonio and Arroyo Valle Reservoirs combined. He shows, by a mass curve study for the controlling dry years, that the Arroyo Valle Reservoir can regulate the floods of this main feeder of the valley to a maximum flow of 250 M. G. D. and that from actual observations of the rate at which the gravels in the valley have absorbed flood waters that were measured, this amount will naturally sink into the underground reservoir. He shows that the floods of the Mocho, except in years of excessive stream flow, all sink without any regulation. He makes a mass curve study of the conditions of the water plane in the underground reservoir during the cycle of controlling dry years and concludes that 55.38 M. G. D. can be safely withdrawn from these gravels. His argument is clear, logical and convincing. The value of this underground storage is enhanced by the fact that it may be used in conjunction with and supplemental to the surface reservoirs on the Peninsula.

Evaporation Loss Reduced to Minimum.

One marked advantage in storing and obtaining underground waters is that they may be handled in such manner as to be practically free from evaporation losses or pollution. The storage capacities of these underground gravel beds are enormous, and as in the case of the Livermore Valley, far in excess of ordinary surface storage reservoirs. The world-wide rule, referred to by Mr. Freeman on page 188, that one should "seldom or never go beyond what the records show can be depended upon during the two or three consecutive years of smallest known discharge" does not apply to these underground gravel beds. The application of such a rule to the water supplies in the Southwest would condemn almost every hydraulic enterprise in that region. While evaporation losses in the arid regions from surface reservoirs through a period of five or six years of holdover is serious, it does not follow that these losses occur when underground bodies of water are covered by eight or more feet of soil.

Livermore Valley Floods.

The estimates which we have made on the water supply from the Livermore Valley are based on mass curves covering a period of the eight driest years, beginning with 1897-8. Mr. Freeman estimates that a material portion of the flood water from the drainage basin tributary to Livermore Valley would pass over the gravels unabsorbed, and he shows the record of daily gagings on the Sunol Dam to confirm his statement (Page 87). This is unfair because:

1st. He selects one of the highest floods of record.

2nd. The greater portion of the high flood waves that pass over the Sunol Dam come from the more precipitous portion of the drainage

basin southeasterly from Sunol, which produce two-thirds of the water crop, which waters do not pass over the Livermore gravel beds at all. If from the waters which pass over the Sunol Dam, that quantity originating in the Calaveras, San Antonio and Upper Alameda drainage area is deducted, then a very different appearing hydrograph than that shown by Mr. Freeman on page 87 will be obtained.

3rd. The saturated gravels of the Livermore Valley cannot act as a regulator when they are already charged as at present, or until the water plane has been lowered by extensive withdrawals.

4th. That with the construction of the Arroyo Valle Reservoir the flood waves that are now being discharged to the Livermore Valley can be regulated, as is demonstrated by Mr. Herrmann for the year shown by Mr. Freeman, at such rate as to permit of their absorption. In dry years there would be complete regulation.

5th. That we have suggested the diversion of the flood waters from the northerly portion of the Livermore Basin on to the gravel beds in the southern portion of the Livermore Valley or on to Sunol Valley. This should be done particularly when the Calaveras and San Antonio Dams are built.

Stream Gagings.

Mr. Freeman makes extensive criticisms of the stream records of the Spring Valley Water Company. This Company has kept a daily record of gage heights and of the quantities of underground water developed in the Alameda Creek Basin for a period of twenty-three years. There is a fair agreement between the computations that have been made by Mr. Herrmann Schussler, Mr. George G. Anderson, and by Messrs. Le Conte and Herrmann, from experiments with models. The record which has been used is that of Mr. Schussler, which is the lowest of the three. The computations by Messrs. Grunsky, Marx and Hyde have not been presented to the Board of Engineers. In a letter which has been written by Mr. Lippincott to the Manager of the Spring Valley Water Company for presentation to the Board of Army Engineers, a copy of which has been sent to the Hydrographer of the United States Geological Survey at Washington, it is shown that the computations of discharge made by the United States Geological Survey for the Niles Dam, and which they specifically state in Water Supply Paper No. 81, are considered inaccurate, were based on testimony given in a certain lawsuit in which fragmentary records of gage heights alone were given for a weir described as 60 feet long. No computations of flow whatever were given in this testimony, nor were they then available. There were no criticisms or corrections made of any computations by the Company, as stated by Mr. Freeman. The original records of computations by the Geological Survey have been examined and they clearly show that no weir lengths in excess of 60 feet were taken into consideration. It is now fully known by all who are familiar with this discussion that when the heights on this 60-foot weir exceeded one foot, the length of the weir became greatly enlarged and for this reason the computations of the Geological Survey show quantities far too small for flood discharges. This government record calls attention to this fact, but there was no adequate appreciation of the extent of this inaccuracy at the time the federal computations were made.

Considering the long gage record on the Niles and Sunol weirs, despite their defects, besides the gagings at Calaveras and Arroyo Valle, and the extensive hydrographic data on the Peninsula, there are few instances in the West where so much is available for the consideration of the engineer engaged in making studies of a new source of water supply.

During the past fifteen years, the City of San Francisco has had under consideration the extension of the water systems for this Bay Region. There has been almost continued discussion of the water supply during this period, and it would appear that the City had plenty of opportunity to have made extended investigations and obtain such data as it might have deemed necessary.

Surface Storage vs. Groundwater.

Mr. Freeman states (Page 160 M.) that the Calaveras Dam should be built to a height of 250 feet, at a cost which he estimates at two and one-half million dollars, that it will require two years to build it, and at least one year to fill it, and that perhaps if he has years of fair rainfall, a supply of 20 M. G. D. may be obtained therefrom while the Hetch Hetchy tunnels are

being driven. As compared with this estimate, we believe that either the Spring Valley Water Company or its possible successor, the City of San Francisco, can take the lands now owned by the Company in the Livermore Valley and in the Sunol Valley, and by the erection of pumping plants and wells at an expense of approximately two hundred thousand dollars, they can get an additional supply greater than this amount within the six months that it would be necessary to install this equipment; that these underground reservoirs are already filled with pure filtered water, the quality of which Mr. Freeman so highly commends; that these diversions can be increased gradually as necessities require, and that the amount of water that can be ultimately so obtained will be double that which Mr. Freeman estimates as available from Calaveras Reservoir, irrespective of whether the years are wet or dry, at a cost of less than ten per cent of his estimate of cost of the Calaveras Dam. Surely under conditions even remotely approximating the figures given above, it would appear that the development of the groundwater supply should precede the construction of Calaveras Dam.

On page 197 Mr. Freeman describes the Sunol filter bed as having its foundation resting for nearly its entire length upon a hard, impervious stratum of mingled gravel, sand and clay. Within the past few months the Spring Valley Water Company has put down several wells in the Sunol Valley and found the depth of open, porous and satuated gravel to be much greater than the average hundred feet that Mr. Hermann estimates he desires to pump from. (See Mr. Herrmann's appendix E for logs.)

Mr. Freeman refers (Page 86) to the surface slope of the Livermore Valley of from 20 to 25 feet to the mile, and that these gravels drain down quickly on account of this slope. This slope we consider a distinct advantage in connection with the pumping of deep wells located in the lower end of the valley. He says: "Long before autumn, whatever storage came into these upper gravel beds during the flood, has drained out down to the level of this outlet". The profiles of the waterplane in the valley and its contours clearly indicate that Mr. Freeman is mistaken. Mr. Williams' profile of the waterplane in the fall of 1911, prepared for Mr. Freeman, shows distinctly a slope giving a rise of 250 feet above the outlet in a distance of six miles.

On Page 68 Mr. Freeman claims that the filtering of turbid flood water into the gravels clogs them, which statement is not in harmony with that on the previous page, which indicates that they now are producing from 8 to 17 M. G. D. by drainage. The Sunol filtration galleries have now been in effective operation for 12 years and are today producing as freely as ever. In the San Fernando Valley very few floods pass entirely over the gravel beds and by the city, and the water issues entirely clear from the lower side of the valley. These gravels are as clean today as ever and who can count the centuries during which this filtration process has been going on. He also states (Page 94) that on the Niles Cone at the extreme lower end of Alameda Creek (where the denser materials naturally would be expected to occur), that 30 M. G. D. of water is absorbed during the floods in about eight miles of river channel, and he states on Page 175 that 14 M. G. D. is extracted from these gravels on the Niles Cone and that they expect to extract much more. He apparently prefers the theory that the gravel beds *ought* to be clogged and filled to the fact that they are not. That the gravels are not clogged is proven by the way in which the flood waters sink not only in the Livermore and Sunol Valleys, but in the Niles Cone (which case he exploits) and rise again in artesian wells and springs and filter galleries, as has been shown in the Livermore Valley, in the Sunol galleries, and in the Niles Cone, and as in fact occur on most of the delta cones of the southern half of California. On Pages 92 and 93 are given nine views showing the great amount of water that can be developed by pumping plants on the Niles Cone, and yet no views nor any reasonable credit is given to the possible development of similar water from the gravels in the Livermore Valley, and slight, if any, mention is given of the large number of natural artesian wells that occur in that region. One is constantly forced to accept Mr. Freeman's own statement of his attitude in this report on Page 194, that "the buyer should have the benefit of the doubt", and regard him as a trader in this case, who is trying to get possession of the Spring Valley System and possibly

is endeavoring to use the Hetch Hetchy rights which he is seeking, as a club to intimidate the owners of the present city water works.

Hydrographic Data Reliable.

Mr. Freeman lays particular stress on the uncertainty and vagaries that occur in estimates of stream flow which are based on computed rainfalls and doubtful percentages of run-off from various types of drainage basins. Apparently the effort is made to throw the responsibility for this method of estimating upon the representatives of the water company.

Mr. Cyril Williams, Jr., working under the direction of Mr. Freeman, has very extensively used this method of determining the water crop from the entire basin, as well as from its various divisions and Mr. Freeman commends and accepts this report. There was less use made by Mr. Freeman of the gagings of the various tributaries than might have profitably been made. Mr. Herrmann has reviewed, in his report, the old records at Calaveras and Arroyo Valle and has deduced a dependable record for 12 years at Calaveras, 5 years at Arroyo Valle, and with these and the Sunol records, Mr. Herrmann makes his deduction. We agree with Mr. Freeman that estimated runoff percentages, based wholly on theoretical rainfall curves, are uncertain and should not be used where stream gagings are available. The only purpose on our part of having considered run-off curves at all was to give a check for our own satisfaction of the statements of stream flow presented by the Spring Valley Water Company, and its distribution to the various portions of the drainage area. It is not necessary to rely wholly on data of this character in these estimates.

We consider that the investigations of the Livermore Valley that have been made by Mr. Fred H. Tibbetts, C. E., are scientific and comprehensive, and we commend them to the Board of Army Engineers. Particularly Mr. Tibbetts' measurements of the movement of underground water in the Livermore Valley (which is at an unusually high rate), show not only the direction of the flow, but its velocity. It demonstrates the porous character of the valley fill. The contours of the water plane, clearly indicate that there is a broad, and sustained movement of the underground waters of the westerly portion of the Livermore Valley toward the outlet of the valley southwest from Pleasanton. This underground body of water is continuous and connected, else these contours of the waterplane and the direction of movement would not be as shown by Mr. Tibbetts. Mr. Herrmann quotes from Mr. Freeman's report on the New York water supply as follows: "Water flows down hill in percolating through porous gravel just as certainly as on the surface and by determining the elevation of the ground water and plotting its contours, the direction of flow and the true limit of the watershed could be made known with certainty."

Valley Fill Is Pervious.

We agree with Mr. Freeman and Doctor Branner that the deposits in the valley fill are in detail lenticular and irregular, consisting of alternate bodies of gravel, clay and sandy loam, but the clay beds are not in the nature of impervious barriers or dikes or broad stratifications, but the alternate bodies of clay and gravel have been laid down irregularly by the floods.

We decidedly disapprove of the efforts that have been made to draw continuous stratifications of valley fill as has been done by Mr. Williams on Pages 89 and 90 of Mr. Freeman's report. Dr. Branner, in referring to the sections presented by Mr. Williams and used by Mr. Freeman on his Page 89, which show continuous stratifications of clay, etc., says that Mr. Williams "has drawn conclusions which a professional geologist would not venture to draw and with which I do not agree".

Conclusions.

In conclusion we wish to maintain—

1st. The reasonableness of developing a large quantity of water which we estimate at 50 M. G. D. from the gravel beds of the Livermore Valley, and that this development does not rely on working along new and uncertain paths, but is based upon a generation of continuous experience in similar localities in California.

2nd. That it is unfair either to the interests of the City of San Francisco or to the Spring Valley Water Company to assume, in presenting this case to the Secretary of the Interior, that the city is in the nature of a buyer entitled to the benefit of the doubt, and that it therefore becomes necessary for the representatives of the

city to depreciate the local water supply and to embarrass the development in the Livermore Valley by skeptical and carping reports and local agitations.

3rd. We have reviewed Mr. Herrmann's report, covering the available water supply from the proposed Calaveras and San Antonio reservoirs and from the further development of the Sunol gravels, and estimating a total water supply from the Alameda Creek of 135.80 M. G. D. While we have not gone through the computations in detail, from our knowledge of this drainage basin and many others in the state, we accept Mr. Herrmann's conclusions as reasonable and the works necessary to control these waters as being within the scope of good engineering practice.

We desire it understood that we are not antagonistic to the Hetch Hetchy grant, when it may be found advisable for the use of San Francisco, and we hope that in accomplishing this purpose her representatives may cease to follow the policy of antagonism and opposition as manifested by Mr. Freeman to the development of local supplies, which we believe to be immediately important for the service of the great area around San Francisco Bay.

During this discussion we have noted nothing on the part of the officers of this Company save a broad minded, liberal policy of assistance to this community either in the way of proceeding with their own developments to meet local requirements, which we know they can supply for a generation to come, and which we know would be a great economic waste to neglect, or in stepping aside in case the City desires to take over the water plant and proceed with a more elaborate metropolitan water system. The engineers of the company naturally object to seeing their work, which is the result of years of careful labor, criticised unjustly and unnecessarily obstructed.

DECIMALS

WITH REFERENCE TO CERTAIN CRITICISMS OF JOHN R. FREEMAN ON RELIABILITY OF HYDROGRAPHIC RECORDS OF SPRING VALLEY WATER COMPANY

BY

F. C. Herrmann,

Chief Engineer Spring Valley Water Company.

In his report on the Water Supply of San Francisco, Mr. Freeman made statements concerning the measurements of flow from the Alameda System, which upon reflection or consideration would have appealed to him as grossly in error.

The one bedrock fact which is the basis for the yield of the Alameda System is the long record of gagings at Niles and Sunol Dams. These records Mr. Freeman criticizes as being unreliable and crediting Alameda Creek with an exaggerated flow. There is not the slightest doubt that Mr. Freeman is in error in these statements, and that his impressions concerning these records were formed by the wide discrepancy existing between them and some incomplete records published in the U. S. Geological Survey Water Supply Paper No. 81, which have been shown to be erroneous.

Where is the Hyde-Grunsky-Marx Report of the Alameda Creek Flow Prepared at Request of Mr. Freeman?

At Mr. Freeman's request a recomputation of flow of Alameda Creek over the Niles and Sunol Dams was made from the original data of the Spring Valley Water Company by Messrs. Grunsky, Hyde and Marx. Our many efforts to obtain a copy of this report from City officials have been unavailing. It would seem inconceivable that Mr. Freeman suppressed the report of these gentlemen because it substantiated the records of the Spring Valley Water Company, yet there can be no other logical inference.

Any unbiased investigator would be gratified to find stream flow records covering such long periods, and it is seldom that an engineer is called upon to analyze a water problem where such wealth of data is available. The longest record is that of the flow of Alameda Creek over the Niles and Sunol dams. This Mr. Freeman attacks because in the computations of flow the ordinary Francis weir formula was used, and dwells at length throughout his report on the fact that no deduction was made for the drowning effect of backwater. That his prejudicial attitude may be understood, it is only necessary to note that nowhere in his voluminous report has he mentioned any factor, the effect of which would increase the flow over that referred to by the Company. The most important factor of this character is that of the velocity of the water as it approaches the dam. In the Alameda Creek with a fall of about 25 feet per mile this velocity of approach in large floods is very great, even greater than that induced by the fall over the dam. Submersion or drowning only occurs in the very high floods and, if Mr. Freeman is familiar with recent experiments on submerged weirs in India and elsewhere, he knows that the backwater below the dam may be above its top as much as from one-half to two-thirds the height of the water flowing over it before the submergence causes retardation of flow.

It has always been known that both the velocity of approach and the submergence would modify results obtained by the use of the Francis formula, though, because it was believed that

in the Alameda Creek the decrease due to submergence nearly offset the increase due to velocity of approach, the conservative results obtained by the Francis formula were used.

It would seem a matter of common sense that the flow of Alameda Creek could not be exaggerated, as Mr. Freeman states, when computed, as in this case with an ideal weir formula, in which no account was taken of the velocity with which the water approaches the dams.

Why Does Mr. Freeman Hope to Discredit the Records of the Spring Valley Water Co.?

In view of these facts, the thought would naturally suggest itself to one who has had the experience that Mr. Freeman states he has had in matters of this kind, that the record of discharge of Alameda Creek as published in Water Supply Paper No. 81, was based upon erroneous assumptions either as to proper gage heights or as to dimensions of the dam or weir, and because of the fact that no effort was made by him to investigate the data upon which the U. S. Geological Survey computations of flow were based (as was done by the Spring Valley Water Company), one can scarcely escape the conclusion that Mr. Freeman referred so often to them to create the impression that the Spring Valley Water Company's records are unreliable, and to support his contention that the Alameda System cannot be made to develop the quantity of water claimed for it by the Spring Valley Water Company.

Review of the original computations of the quantities given in Water Supply Paper No. 81 reveal the fact that, although they were based upon the ordinary Francis formula, an erroneous length of weir crest was used for flows when the depth of the water over the dam was in excess of 12 inches.

Errors Due to Misplaced Decimal Points.

Mr. Freeman has endeavored to impress his readers with the unreliable computations of flow of Alameda Creek made by the Spring Valley Water Company, and adopts a lesser yield from that System than claimed for it by the Company because of the discovery of the misplacement of a "*decimal point*" in one of the annual quantities of run-off. To add to the seriousness of this error, Mr. Freeman stated that the records, which included this erroneous one, were testified to in the U. S. Circuit Court by Mr. Schussler. Had Mr. Freeman continued his investigation of *this very same* Court record, he would also have discovered that correction of this record was made by Mr. Schussler.

Had Mr. Freeman been as careful in watching the decimal points of his own computations, he would not have fallen into the error of stating that the San Miguel (Rock Creek) Reservoir with a total capacity of only 500 M. G. would supply the present demands of San Francisco for 4½ months (135 days), in case of a break in his proposed Hetch Hetchy conduit, when as a matter of simple arithmetic it would last only 13½ days. Under state of complete development even the short period of 13½ days will be greatly reduced. Nor would he have given the elevation of San Miguel Reservoir at 38.5 feet instead of 385 feet when he considered the feasibility of conducting water thereto from Lake Chabot, which according to Mr. Freeman's proposed plans will be raised to an elevation of about 350 feet.

Further, it is to be noted for the sake of the record that Mr. Freeman's correction of the misplaced decimal in the Spring Valley Water Company's record needs correction, for in his ambition to minimize the flow from Alameda Creek, he applied a correction to the amount of water pumped at Belmont, which was in nowise in error. The final result, therefore, is that the run-off at Niles dam for the season 1897-98, corrected by Mr. Freeman as 3612 M. G., should be 3775 M. G.

Storage Minimized Without Good Reason.

Another remarkable attitude taken by Mr. Freeman is that with regard to storage in the Alameda System. As in all Western projects, the safe yield of the Alameda System depends very largely upon storage. Depending upon the gross run-off the greater the storage the greater will be the safe draft that may be made upon the System. Mr. Freeman uses the results of his assistant, Mr. Williams, as to the safe draft from the Calaveras Reservoir of 30 M. G. D. based upon a storage capacity of only 28,800 M. G., resulting in a large amount of waste. This is hard to understand in view of the fact that Mr.

Freeman, himself, prior to the time Mr. Williams began his work, designed the Calaveras Reservoir for a maximum storage of 52,000 M. G., or nearly double that used by Mr. Williams. Had Mr. Williams used the storage planned by Mr. Freeman, he would have found a safe gross draft of about 47 M. G. D. from the Calaveras Reservoir, and had he used the proper stream flow instead of those estimated by him at a flat rate of 40% of the volume of Sunol and Niles dams, he would have found the safe gross draft of Calaveras Reservoir to be about 60 M. G. D., or 50% more than Mr. Freeman reckons can be developed by the whole Alameda System.

Similarly, Mr. Williams, whose results Mr. Freeman accepts, minimizes the safe draft from the Arroyo Valle Reservoir by limiting the height of the dam because of foundation conditions, while Mr. Freeman in his report to the City says these conditions are amply good for a dam high enough to conserve all the stream flow.

With the limited storage upon which Mr. Williams has based his calculations there would also be an enormous amount of waste from the Arroyo Valle Reservoir, which would have been very largely conserved had he used the proper storage capacity. In this case he would have obtained a gross safe yield very much larger than that given in his report.

What Are Reservoirs for?

Mr. Freeman would limit the length of time that the water surface of a reservoir may be held below its flow line, because of a fictitious belief on the part of a few Eastern engineers that weeds will spring up on the uncovered margins of the lake. All reservoir margins should be kept clean. However this may be, under his contentions withdrawals might be stopped with reservoirs still holding ample water. In this connection, it seems strange that Mr. Freeman puts a limit of this sort on the reservoirs of the Spring Valley Water Company, while in his approval of the Los Angeles Aqueduct, conceived, designed and built by Mr. Wm. Mulholland, he regarded no such limits as essential or even worthy of remark. The plans of the Los Angeles Aqueduct call for the building of Long Valley Reservoir to tide over "a series of dry years." Mass curve studies made at that time show that, over a period of 50 years, the water surface in this reservoir would be below the flow line continuously for one period of 14 years and two other periods of 9 years each. The natural inquiry is why this should be allowed in Los Angeles and denied to San Francisco?

Geology of Livermore Valley Determined Sufficiently to Prove Water Capacity

Mr. Freeman classes the Livermore gravels with mining, evidently intending to convey the idea of uncertainty; or undermining. To support his conclusions in this regard he reproduces from Mr. Williams' report what purports to be geological sections, but of which Dr. J. C. Branner says:

> "The two hundred and more well logs examined by us show that this statement is quite misleading. In the southwest end of the valley, especially near the pumping stations, the wells are close enough together to enable one to identify the beds from one well to another, but when the distance between wells amounts to 500 or 1000 feet, to say nothing of a greater distance, one can feel no confidence in such correlation. The conditions under which the valley was filled preclude the probability, or even the possibility, of continuous beds over the entire valley. Indeed, at page 384 of his report, he himself speaks of the sections as showing "a far from homogeneous or continuous formation in the upper gravels." Finally, I have not attempted to take up all the geological points mentioned in Mr. Williams' report, and I doubt the necessity of my doing so. I realize, as Mr. Williams probably realized himself, that he had a vast amount of miscellaneous but incomplete geological data from which he has drawn conclusions that a professional geologist would not venture to draw, and with I do not agree."

Yet in the investigation of the underground waters of Brooklyn Mr. Freeman states that not only can the available supply of water be very closly estimated, but that he considers underground waters as better, safer and cheaper than surface waters. In this connection, it should be borne in mind that geological conditions, as determined by Drs. Branner and Lawson, are much more favorable for the storage and retention of water in the gravels of the Livermore Valley than they are in Long Island.

Mr. Freeman finding himself generally in accord with Mr. Williams, relies upon a set of meas-

urements of water surfaces in wells covering a period of 100 days for the determination of the safe yield of Livermore Valley.

Fallacious Deductions in Livermore Valley.

The fallacies of the deductions from these measurements are:

First, that the evaporation from soils surcharged with artesian water was not considered;

Second, that error was made in proposing to unwater only one end of the 100-foot prism;

Third, that there was insufficient data to determine the water contours;

Fourth, that assumption of porosity of the valley fill was based upon the erroneous "geological sections" made up from certain well logs in some instances over a mile apart.

Giving due consideration for these various factors, it will be found that the safe draft from the Livermore Valley upper gravels will be about four times what Mr. Williams suggests, or over 50 M. G. D.

METHODS PURSUED IN ATTACK ON THE RESOURCES OF THE PRESENT WATER SUPPLY OF SAN FRANCISCO

ILLUSTRATING THE DESTRUCTIVE CAMPAIGN CARRIED ON WITH STUDIED AND PERSISTENT EFFORT TO DESTROY CONFIDENCE, PROMOTE ATTACK, AND TO UNDERMINE THE INTEGRITY OF THE POSITION OF SAN FRANCISCO'S WATER SUPPLY.

In paragraph 66 on page 80 of the report of John R. Freeman on "The Hetch Hetchy Water Supply for San Francisco," in discussing the yield of the present sources, Mr. Freeman states in part when dealing with the subject of underground waters in the San Francisco Bay region that "**the data now in course of collection at my request, by Mr. Dockweiler,** indicates that the plane of saturation is already being pumped below sea level over large areas."

Again he states in paragraph 67, with reference to the Niles Cone region . . "I have been informed that the Spring Valley Water Company was prevented* from withdrawing waters from lands which it had purchased near the Bay shore at Ravenswood on which it had sunk deep wells which it soon quit pumping because of injury found or expected to occur to the sources used for the supply of communities in the vicinity of Palo Alto" . .

On page 189 of Appendix 4 to his report, relating to the dependable yield of Alameda Creek, he states: "**Beyond this there must be considered the questions as to whether the complete diversion of every gallon of flow from the Niles Canyon will be permitted by the farmers and other local users of ground by pumping, and by the courts, for so long a period as six or eight years.**"

On page 192, when treating of the expediency of building reservoirs, he states: "The question may also very properly be raised, if on a broad view of the situation it will not be better for the cities and for California as a whole to leave all the water that will remain after the Calaveras and Alameda Creeks have been dammed and diverted, for local use in agriculture and manufacture within the Livermore Valley and on the Niles Cone."

*This is without foundation.

MASS MEETING.
CENTERVILLE, NEAR NILES.
TOWN HALL.
MONDAY, OCT. 30, 1911.

TEMPORARY CHAIRMAN C. RUNCKEL (EDITOR "WASHINGTON PRESS", A NEWSPAPER PUBLISHED AT NILES.)

J. H. DOCKWEILER, ENGINEER, APPOINTED BY JOHN R. FREEMAN, TO WORK UP DATA FOR HIM WITH REFERENCE TO THE POSITION OF THE SPRING VALLEY WATER COMPANY RELATIVE TO THE NILES CONE.

Speech of J. H. Dockweiler from the notes of T. J. Wilder taken at the meeting.

J. H. DOCKWEILER, SPEAKER.

Every community requires the best source of water supply possible. The *source* being the primary requisite and the *price* to obtain water from that *best source,* a secondary consideration.

The City of San Francisco is to get its water from the Lake Eleanor and Hetch Hetchy. Before bringing its waters from the mountains it will first acquire the Spring Valley properties and thus be able to store its mountain water in the reservoirs now owned by Spring Valley Water Company.

The local supply however, will be sufficient for some time to come, but as we all know, water cannot be manufactured and consequently when the demand becomes greater the necessity for the taking of more water becomes apparent and as you know that increased demand will have to be satisfied from this Alameda Watershed.

I do not think it just, that one community should be able to take more water than it can use, at the time of taking, from another community which latter has need of it for irrigation. For a city is as limited in its growth as the limits of its water supply and right here **you have the condition of the privately owned Water Companies, taking water from a district that needs it and as a consequence the growth and development of this territory will be checked, if it has not already so suffered.** And what makes it worse here is the fact that San Francisco, Oakland, Berkeley, etc., **could get their water from a region where there is plenty and where none is required for irrigation, namely, the Sierras.**

To illustrate the way in which these privately owned companies get water rights years in advance of the time they will need the water: In 1874 the Spring Valley Water Company bought the Calaveras water rights, paid $1,000,000 for them, but not a drop of water was diverted for its own use until 1888. **From all this it would seem to have been decidedly more just for the Water Companies to have taken and to continue to take only such water as is needed for its immediate needs** and to go into the mountains when the growth of the cities shows that a heavy tax will be necessary on the watersheds in this fertile country. Instead the water companies bought and continue to buy lands and rights that are not needed for present use but are purchased simply to reserve them for future needs, and now these Companies own thousands of acres of land which they are simply holding in anticipation of the future. **I believe the situation in a nutshell to be this: The Water Companies should be allowed to store only enough water for present use, from these lands, and the balance should go towards the irrigation and local use.**

In 1899 the Legislature passed an Act known as the Municipal Water District Act. The object being to enable several communities to incorporate and by sharing the expense of bringing in the water make the burden easier as it could of course be done cheaper, there being but one set of officers necessary under one management. The District would sell the water wholesale to the different communities, who in turn would dispose of it at retail to its inhabitants.

The condition here in Niles Cone is serious. As you can plainly see, it spells havoc for this district if the time comes when more water is taken from Alameda Creek than is contributed to it annually. Hence it follows, that if your wells are not as plentiful as in former years the reason must be due to the fact that too much water is being taken from these lands now, and as more and more is taken, so will the wells become less and less plentiful. Here is your case, then, Ladies and Gentlemen, for the courts do not accept theories in deciding cases—if you can show by observation of the actions of your wells that the water is being depleted through the Water Companies taking too much water from these lands, then you would have a case, and a strong one, but you must have the facts which can be obtained by the observation of your wells.

I believe your salvation lies in backing San Francisco in its fight for Hetch Hetchy. The City has voted $45,000,000 in bonds for this supply, these bonds have been passed upon by one of the biggest bond houses in the United States, so that there is no reason why the thing should not be put through. Unless these waters of the Sierra's are brought into San Francisco, more and more water will be taken from these Alameda Creek watersheds and as a consequence the condition of the people of this region becomes worse and worse. There is absolutely no other way out of this condition of things except to bring in the Hetch Hetchy waters and for the people of Oakland to purchase the Peoples Water Company and the people of San Francisco to purchase the Spring Valley plant.

My advice to the people of San Francisco is to buy the Spring Valley Water Company, lock, stock and barrel. **I am afraid of these subsidiary corporations of theirs and therefore urge the purchase of everything they own.** When Captain Payson made an offer to sell the Spring Valley Water Company for $32,000,000, I was present, and I immediately urged upon one of the supervisors that they get the offer in writing at once and snap it up.

Question: Mr. Dockweiler, did not the Water Company win a recent case against the City of San Francisco, the decision being given by Farrington?

Dockweiler: **Well, they claim to have won. I want to say that two decisions like that one would put them out.** I can't see how they claim to have won when the court sets a valuation of $25,000,000 on a property which their engineers have claimed to be worth anywhere from 40 to 70 millions.

Question: Did not the City make a mistake when it failed to purchase Spring Valley for $35,000,000?

Dockweiler: It certainly did.

Question: What are the Spring Valley's plans for the future?

Dockweiler: Well, I have not been the confidential man for Spring Valley and everything I have learned about its plans, etc., I have gained through hard knocks. However, there is such a thing as "moral certainty" and I know of moral certainty many things but could not state them here as facts. Their Chief Engineer has stated that they intend to build a reservoir on the San Antonio, the Calaveras and the Arroyo Valle. **So you see there won't be much left when they get through.**

RESOLUTION ADOPTED AT MEETING.

"Resolved, That we view with the gravest anxiety the situation that is being forced upon us, and earnestly pray that every effort be made by San Francisco, Oakland and other Bay Cities to hasten the time when they shall draw their water supply from the Sierra Nevada Mountains, and to the end that the splendid resources of our township may be conserved and devoted to the uses which nature has ordained; and be it further

"Resolved, That we petition the Federal Government to speedily grant the City of San Francisco the Hetch Hetchy water supply, that the further diversion of our water supply, with the consequent devastation to our township and county may be stopped."

Meeting adjourned.

MASS MEETING

TO CONSIDER THE

Water Supply Question

At Town Hall
CENTERVILLE

Tuesday Eve. May 28

Addresses by J. H. Dockweiler of San Francisco
and Other Speakers. Everybody Come.

Important Notice!

Property owners in Washington Township are urgently requested to furnish information to H. A Noble, Assistant to Consulting Engineer of San Francisco, now at work here. It is of the highest importance to our people that all information be given freely and promptly.

SIGNED:---
CHRIS RUNCKEL
F. V. JONES
J. B. FAIR

Press Print Niles

Committee Associated Chambers of Commerce.

Photographic reproduction of notice posted in conspicuous places throughout Niles region. Copy is about one-quarter size.

NOTE: Runckel is editor of The Washington Press, of Niles.

The Washington Press
THE ALAMEDA COUNTY PRESS
NILES, ALAMEDA COUNTY, CAL., FRIDAY, MAY 24, 1912

MASS MEETING

Will Be Held Next Tuesday Evening at Centerville.

Citizens of Township Will Consider Water Supply Question.

A meeting of the citizens of Washington Township will be held in the Town Hall at Centerville next Tuesday evening. It has been called by the Associated Chambers of Commerce to consider the water supply question. Since the meeting called by the Press last fall the developments on the water question have come thick and fast. The danger which we pointed out at that time is now more fully realized because more evidence has been brought to light to substantiate our assertions. The acquisition of the large holdings of land near Newark by the Union Water Co., the boring of wells by that company upon the land acquired, and the general unfolding of their plans has brought home to our people a sense of a new danger that is quite imminent. Added to this is the danger that the People's Water Co will be compelled to increase its demands upon our section and the likelihood that the City of Oakland will soon become the owner of that system and will follow up that move by another to embrace our entire district in a consolidated city and county government and thus prevent any action on our part as a community to defend our interests. The likelihood that the Union Water Co. will be absorbed by either the Spring Valley interests or acquired by the City of Oakland adds further to the menace. And overshadowing it all is the enlargement of the Spring Valley Water Co.'s plan to block the Hetchy Hetchy enterprise until the City has been forced to pay the added millions which it has piled upon its price of two years ago. During the past few months the secret operations of this company at Pleasanton have been revealed. Its claims for a greatly increased water supply from the Alameda Creek watershed have been unfolded. The gigantic nature of the contest to gobble up all the available surface and underground water supply by these three companies has been made plain to our people. Our very future prosperity is threatened more ominously than ever. The time for action was here a year ago but our people could not be made to see it. Every day adds to our danger and calls for prompt action if we as a people are to safeguard our interests. The stake is a big one and is being played for by powerful interests. If any action is to be taken it must be taken NOW or it may be years before we can even attempt to extricate ourselves from the net that is being woven about us.

The Press has repeatedly warned our people of their danger and has repeatedly urged them to united action. Again we urge our people to attend the meeting at Centerville next Tuesday evening. If there is a way left us to escape with safety let us try to find it.

Let every citizen who would guard the best and highest interest of our township attend the meeting. Urge your friends to come. Let us get all the light we can on the subject, bring all the information we can to the meeting and be prepared if possible to evolve some plan to protect the future prosperity of our section.

It is of the highest importance that the meeting be well attended.

The Committee in charge has asked J. H. Dockweiler, Consulting Engineer of San Francisco to again address our people. He is probably more conversant with the water problem than any man in the State and will surely be able to answer any questions which our people may ask of him

LIBRARY COLUMN

SEND IN YOUR DATA

If any property owner in this township has measured the depth to water in the past two or three weeks it would be well to send the information to The Press office immediately. After this week we shall not ask for any further data as the report to the government must be filed next month and no more data from us can

The Washington Press
THE ALAMEDA COUNTY PRESS
NILES, ALAMEDA COUNTY, CAL., FRIDAY, JUNE 14, 1912

IMPORTANT MOVE MADE ON WATER QUESTION

Companies and Cities Warned Further Drainage Will Be Resisted.

The first important step on the part of the people of Washington Township to resist the further aggressions of the Water Companies was taken this week. At a joint meeting of the Water Committee appointed at the recent mass meeting in Centerville and the Associated Chambers of Commerce held in Niles, Thursday evening, notice to the Water Companies was submitted by the committee and after a lengthy and exhaustive discussion of all phases of the question, the Associated Chambers unanimously indorsed the report of the Committee and recommended that each local Chamber of Commerce be asked to approval to the action taken mittee and support the ...er assembled in reference to the taking of waters and the threat to further take more waters from below the surface of the ground, a motion was unanimously adopted that the Chairman of said Meeting, Mr. Joseph C. Shinn, appoint a Committee of five land owners of said Washington Township with authority to represent the Mass Meeting and to serve notice upon

The Union Water Co.,
The Peoples' Water Co.,
The United Properties Co.,
The Spring Valley Water Co.,

and all other corporations or persons who may be concerned, notify them to

TAKE NOTICE

We have been informed that you or some of you are commencing work which would indicate

The Washington Press
THE ALAMEDA COUNTY PRESS
NILES, ALAMEDA COUNTY, CAL., FRIDAY, MAY 31, 1912

LET EVERYBODY HELP SAN FRANCISCO IN MAKING OUR FIGHT

Every property owner of this township who has any interest in its future development should help to give H. A. Noble and his assistants all the information possible. This is the first time any effort has ever been put forth to get the evidence that shall protect our water supply. San Francisco is spending thousands of dollars in doing a work that will help our section more than it will help that city. We have been sold out and bunkoed so often in the past that it is hard for our people to realize the unselfish work now being done by the great city on our water supply question.

We ought at least be willing to help ourselves by letting others help us. Let every property owner in the district being covered make it his business to secure all the information possible for the men now at work here. Talk it over with your neighbors. Explain the situation. Get them to help. The time is short. The data must be secured in a few days. The more complete it is the better for us all. This is the best opportunity our people have ever had to protect their own property. It surely never will be done for you again FREE OF COST. Get all your information to the people at work here and don't wait to be called upon.

Hunt up Mr. Noble and help him out. His headquarters at present are at the Belvoir in Niles.

The Washington Press

THE ALAMEDA COUNTY PRESS

NILES, ALAMEDA COUNTY, CAL., FRIDAY, JUNE 7, 1912

Do You Realize What This Means

It seems almost inconceivable that the importance of the work now being done by the city of San Francisco in our midst could be misinterpreted or misunderstood or lied about. And yet it is so.

Suppose you ask yourselves these questions: Do you want the people of San Francisco to believe that they can get all the water they need from the Alameda Creek watershed? Do you want the United States government to believe it?

Or do you believe San Francisco should go to the Sierra's for its rapidly increasing needs?

Do you want to show that no more water can be taken from this district without injuring this district?

If you do, then help San Francisco to know what it has meant already to take 16 million gallons of water every day from a section that needs every drop of water it can get. Help them to realize what it will mean to take twice or three or four times that amount.

Do you realize what that means to the future of our section? Do you realize what it means to your own property?

If our people could but realize the nature of the danger now threatening them, they would be up in arms. We have warned you repeatedly. The time is here now, RIGHT THIS WEEK to protect

How to Help on the Water Question

Do you as a property owner in this township want to help protect your water supply You can do it if you wish but you must do it right now. Before another issue of The Press reaches our readers the evidence concerning our water supply will have been gathered. Whatever that evidence shows will be used by the city of San Francisco in the hearing before the Board of Army Engineers in Washington. The better the showing the more certain will be the protection afforded our people in the near future. The time for appealing to our people to do something for themselvas is now past. Those who are making the investigation want the fullest evidence. So far, although much effort has been made to get it, the evidence is still very incomplete. Here is how you can help: Measure the depth down to the water level in your well. Send the result of your measurement to H. A. Noble at once or send it to The Press office and we will turn it over to Mr. Noble. If your well has not already been measured get busy yourself and do this right away. Don't delay it. DO IT NOW. Measurements are desired from every well in the township if possible.

Answer these questions right away.

How far from the surface of the ground is the water in your well!

Is it further now to water than it has been in the past? How much?

Whatever data is gathered will be a public recore.

It is of the GREATEST importance that this knowledge is obtained at AT ONCE. Will you help your own cause by taking a half hour to help get this information?

Niles Notes

ley at the opening of the new year of study, and ... forth

ASSO[...]

The Washington Press
THE ALAMEDA COUNTY PRESS
NILES, ALAMEDA COUNTY, CAL., FRIDAY, AUGUST 2, 1912

REPORT ON NILES CONE

Engineer Dockweiler Files His Report to Army Board.

Late on Wednesday night of this week the report of Consulting Engineer J. H. Dockweiler of San Francisco on the water supply question was ...ith the Board of Army Engin... ...v people who are not ac... ... the scope of the work ...mport-

WATER MEETING WELL ATTENDED

Water Supply Question Ably Discussed.

The meeting held at Centerville last Tuesday evening to discuss the water supply question drew out a good audience. Although no effort was made to drum up a crowd, the town hall at Centerville was well filled by an interested body of property owners of the township. One of the features of the meeting was that it was almost exclusively made up of men. J. C. Shinn acted as chairman. The purpose of the meeting was stated by C. Runckel, of the committee of the Associated Chamber of Commerce. The meeting was called at the request of a number of citizens of Centerville and was to have been held the latter part of last month, but was postpend to the present time owing to the pressure of other questions.

J. H. Dockweiler, consulting engineer of the city of San Francisco, was the speaker of the evening, and in a very able manner convinced the audience of the liberal attitude of that city on the water question. Mr. Dockweiler stated that the city was preparing a report at the suggestion of the federal army board of engineers, which is to pass upon the Hetch Hetchy case in the near future. The city authorities are gathering data on all available water supplies that may be utilized by the city. The investigation of the Niles cone ...portant relation to the ... supply.

The Washington Press
THE ALAMEDA COUNTY PRESS
NILES, ALAMEDA COUNTY, CAL., FRIDAY, AUGUST 2, 1912

MEASURE THE WATER IN YOUR WELLS.

We urge upon our people the immediate necessity of keeping at least a monthly measurement of the depth to water in the wells. If your well isn't fixed so you can make these measurements a very trifling expense of boring an opening so that it can be done should be met at once by every owner of a well. This data should be secured and gathered during the next two months. It is VERY, VERY important that it gets into he hands of he proper people before the final decision is made by the government. **We appeal to our people to see that it is done.**

In the near future the Press will give its readers a more complete of the report that was filed this week.

The Washington Press
THE ALAMEDA COUNTY PRESS

Why Logs of Wells Are Necessary

What is the log of a well? We have been asked this question. It is the description of the nature of the earth through which your well is bored. For instance a well may be bored the first 18 feet through silt and the next 20 feet in gravel. Or it might be 18 feet of silt or loam, 40 feet of clay and 5 feet of gravel, etc. A description of the diferent kinds of earth through which the well is bored is the "log of the well."

If the logs of many wells throughout the township are studied we can tell pretty accurately what the underground formation is, where the water comes from and what effect the taking away of large amounts of water will have on our underground water supply. [illegible] more logs of wells we have the [illegible] our people will know of the [illegible] situation and the more wisely they can [illegible] to protect themselves.

The work now being done by [illegible] Francisco is the most valuable work ever done for our people in this township. And still many of our people are slow to realize it. Have you the log of your well? Do you know who bored it? Send your information at once to H. A. Noble, Hotel Belvoir, Niles, Cal.

Decoto

The Washington Press
THE ALAMEDA COUNTY PRESS
NILES, ALAMEDA COUNTY, CAL., FRIDAY, AUGUST 9, 191[illegible]

Something for Pleasanton to Ponder Over.

The town of Pleasanton is confronted with a situation as a result of the acquisition of so much of its very best land by the Spring Valley Water Company that ought to give its people an opportunity to realize what has been done to the future of the town, and what might have been the situation had there been a more public spirited course pursued by its political leaders.

The very future of the town hinges upon the outcome of the present controversy between the Spring Valley Water Company and the city of San Francisco. In spite of the apparent policy of the Spring Valley Water Company to offer liberal terms to leasers of its lands, the fact remains that with the title of so much of its [illegible] in the hands of one great [illegible] expect that full hold of the Spring Valley Company on the Pleasanton section, the men who have long been the political dictators of Pleasanton had marked out a policy that would have served notice on the company that its efforts to further intrench itself would be resisted. Suppose these men had thought of the future of their town that had always so generously supported them, and had united the sentiment against further aggressions on the part of the water company. Suppose they had co-operated with the people of Washington township in fostering a union for the protection of the water supply for actual settlers, and had enlisted the support of the entire county to fight off this menace—would the Spring Valley have been so eager to buy up [illegible] land, knowing that it [illegible] increase the

THE BOUNDARIES AND AREA OF THE NILES CONE

FROM A STUDY OF THE GEOLOGY OF NILES CONE AND THE SURROUNDING COUNTRY

BY

DR. J. C. BRANNER,
Geologist.

Leland Stanford Junior University.
Office of the Vice-President.

Stanford University, Cal., March 21, 1911.

Spring Valley Water Company,
San Francisco, Calif.

Gentlemen:

I have gone over the region about Niles and west, southwest, and south of that place, with a view to determining the probable area over which the underground water supply is likely to be affected by the diversion of the waters which, under natural conditions, are discharged through the Niles Canyon. I am also acquainted with the geology of the Niles Canyon, and of the Mount Hamilton range, from which the Alameda Creek receives its waters.

The General Geology.

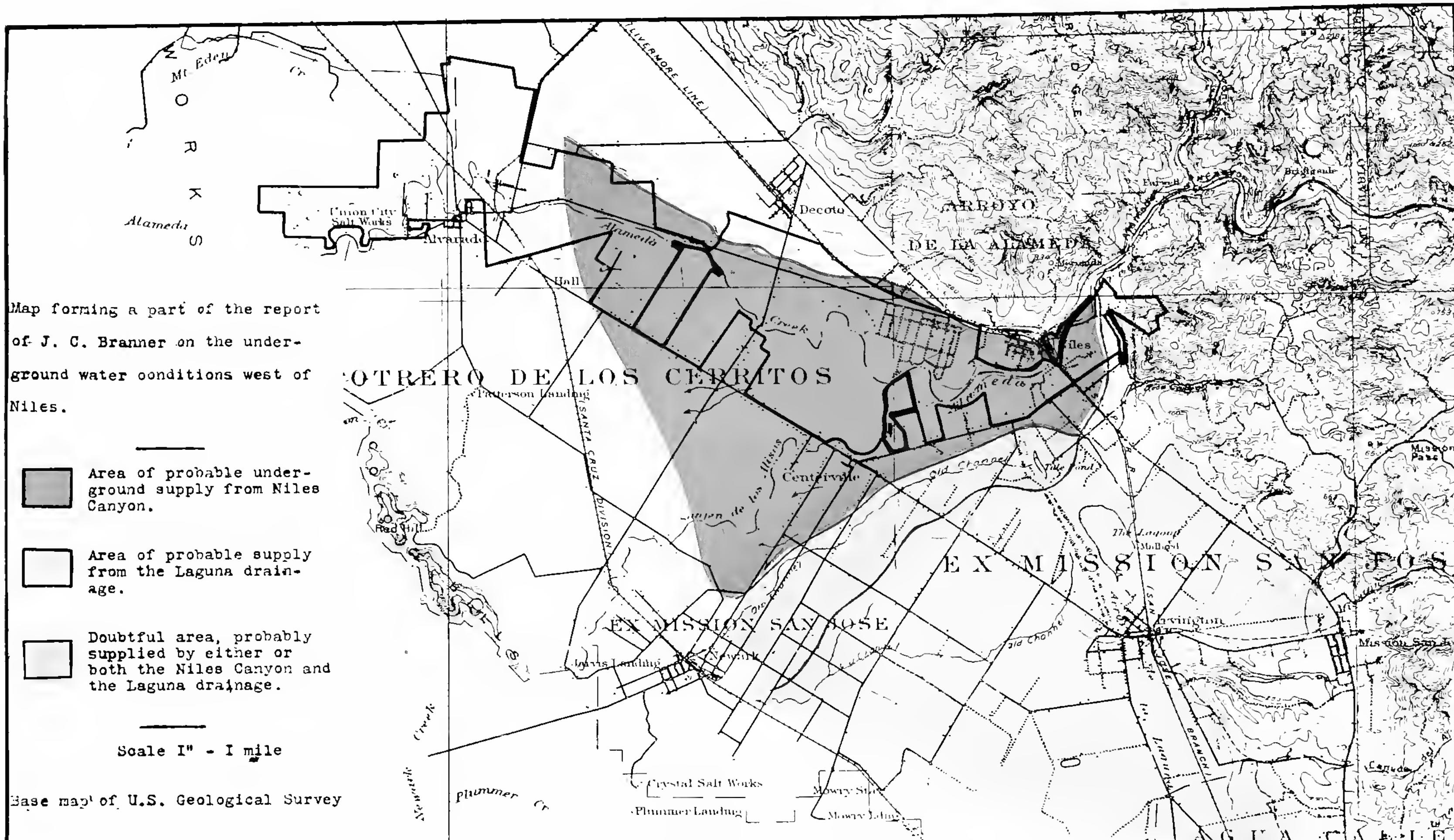
The question of the subterranean waters in the region under consideration is directly related to the geology of the valley floor in the area between the Coyote Hills west of Newark and the Contra Costa range at Niles and northwest and southeast of that place. The geology of the Contra Costa range of mountains and of the Coyote Hills is entirely different from that of the valley. The former are composed of old, hard rocks that are usually much folded, while the valley is filled with loose materials of various kinds that have been washed down from the higher grounds of the mountains.

In order to understand the origin, materials, and method of formation of the valley floor, we must go back in our imaginations to a time when the valley between the Coyote Hills and the mountains at Niles was considerably deeper than it now is. The streams flowing from the mountains on the east and northeast brought down sands, gravels, clays, and all kinds of silts, and deposited them along the bases of the hills and spread them out over the low lands. This process of filling up the valley has been going on for a long period of time. Naturally the larger streams brought down more materials than the smaller ones and spread these materials over wider areas, but always with that irregularity and patchy distribution commonly observed in stream and flood-water deposits. Just what areas have been filled in by this and that stream cannot be stated with absolute precision, but in a broad sense it is reasonable to suppose that the areas covered by floods of the streams of the present time closely approximate the areas filled in by those same streams in the past.

For example, it seems probable that the materials of the valley floor at Decoto were brought down from the mountains north and east of that town, the materials on which the town of Centerville stands, came down through the Niles Canyon, while the materials of the plain about the town of Irvington were brought down from Mission San Jose and from the mountains east of Irvington.

Origin of the Underground Waters.

The history and nature of the deposits forming the valley floor and the well-known behavior of the streams of the region especially during the dry weather show beyond reasonable question that the waters found



DR. BRANNER'S MAP OF NILES CONE.

in the deep wells over the valley are those that soak down through the gravels, especially about the margins of the beds where the materials are usually coarsest. It follows that the diversion of any one stream must affect the underground water supply of the area fed by that particular stream.

Limited Area Supplied by Niles Canyon.

The accompanying map, forming a part of the report, shows in red the area believed to be supplied by waters fed into the valley gravels by the Alameda Creek where it enters the valley near Niles.

This area forms a triangle having the mouth of Niles Canyon at its eastern apex, the town of Newark at the southern apex, while the northwestern apex is about one mile northeast of the town of Alvarado.

It should be noted, however, that while there can be no serious question about the underground waters of this area coming from the Niles Canyon, as the distance from Niles increases, the difficulty of proving that the underground water actually comes from that canyon increases proportionately.

For this reason the area shown on the map cannot be extended further toward the west, northwest and southwest with certainty. Whether the diversion of the water from the Niles Canyon has affected the wells of the valley is a matter that can be determined only by well records.

A Doubtful Area.

I have indicated as doubtful a strip of land beginning at Tule Pond, a mile south of Niles, and running southwest in the direction of Newark. This belt is now without direct connection with the drainage from the mountains. There is evidence of an old drainage that formerly flowed through a gap in the low ridge west of Tule Pond, and followed along this belt in the direction of Newark. The low ridge that shuts in Tule Pond on the west has the appearance of a break made at the time of an earthquake and this break has brought about a rather recent change in the drainage. The position and direction of this doubtful zone suggests the possibility of its having formerly been the area or part of the area along which the water from Rose Canyon flowed across the valley.

The Laguna Drainage.

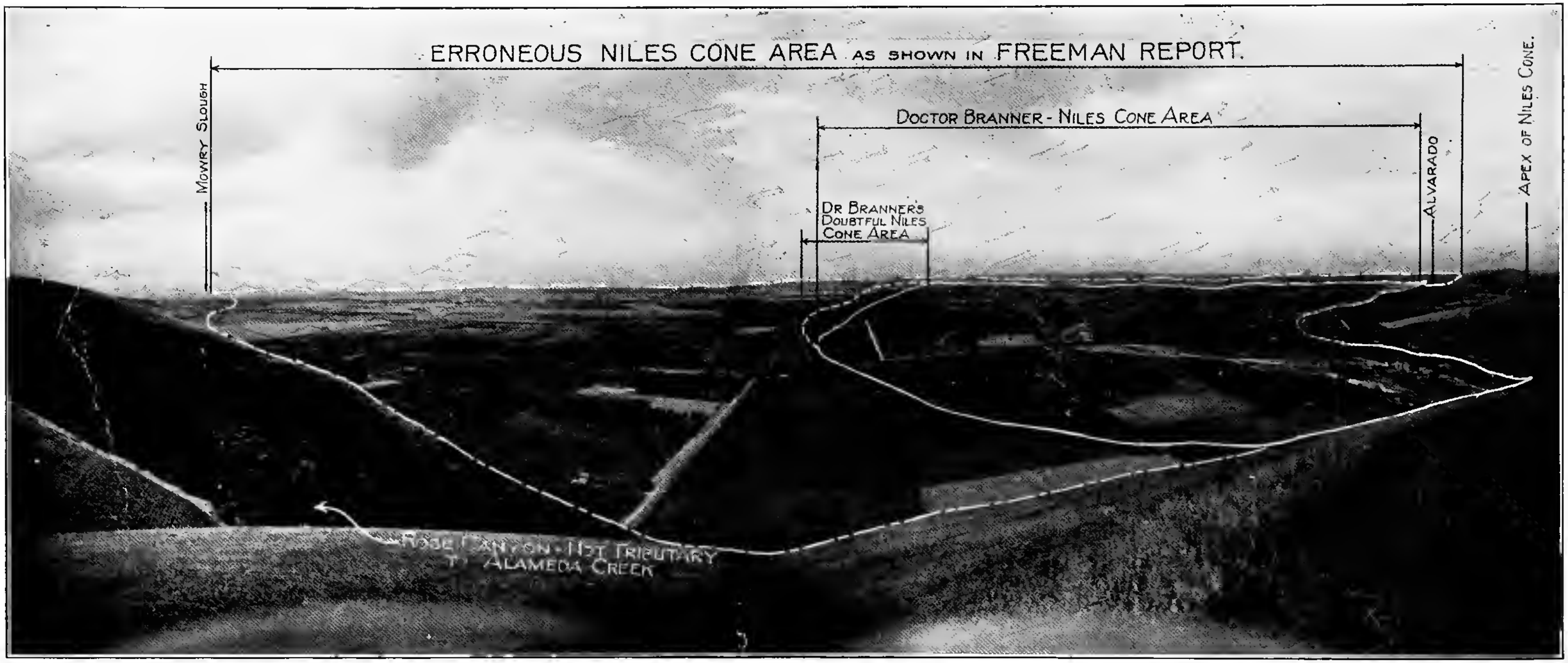
The low relief of the valley floor south of Niles might lead one to suppose that the entire region between Niles and Irvington received its underground waters from the Niles Canyon. This, however, is not the case. The water from Rose Canyon, a mile southeast of Niles, runs southward and flows into the Laguna north of Irvington, while all of the drainage from the mountains from Rose Canyon southeastward to Mission San Jose flows into that same Laguna, and overflows towards the south. It is therefore to be assumed that the underground waters of the Laguna area follow approximately the same course as the surface waters and supply the region south and east of the zone marked as doubtful on the accompanying map.

Peculiarities of Chemical Analysis in Endeavor to Trace Origin of Underground Waters.

I have read the report of Professor E. W. Hilgard upon the waters of the region here discussed. I hold Dr. Hilgard in the highest esteem as a geologist and as a chemist, but I am obliged to disagree with him in regard to the probability of the waters of the region under consideration having come from the southern end of the Santa Clara Valley. The peculiarities brought out by the analyses of the well waters are interesting, but in my opinion the explanation of their composition must be sought within the drainage area of the streams that now flow and have been flowing into this part of the valley for a very long time. The theory of the reversal of the Santa Clara Valley drainage is not tenable.

Yours respectfully,

J. C. BRANNER.



"CORRECT AND INCORRECT NILES CONE AREA."

Acreage of Niles Cone by Dockweiler accepted by Freeman.......... 47,360 acres
Acreage of Niles Cone by Dr. Branner.......... 8,860 acres

This picture conveys the impression that the apex of the Niles Cone is in the foreground at the outlet of Rose Canyon, instead of at the extreme right, one mile to the north.

Note:—On page 200 of his report Mr. Freeman qualifies Dr. Branner as follows, "There is no man living better qualified than Dr. Branner to speak with authority upon the geology of this region."*

*Livermore Valley.

WHAT ARE THE WATER REQUIREMENTS OF THE NILES CONE?

BY

F. W. Roeding.

Manager of the Agricultural Department of the Spring Valley Water Co.

Mr. Roeding was Irrigation Manager of the Irrigation and Drainage Investigations of the United States Department of Agriculture.

In Charge of the Central Division comprising the States of Colorado, Wyoming and Texas, and later in charge of the Pacific Division, comprising the State of California.

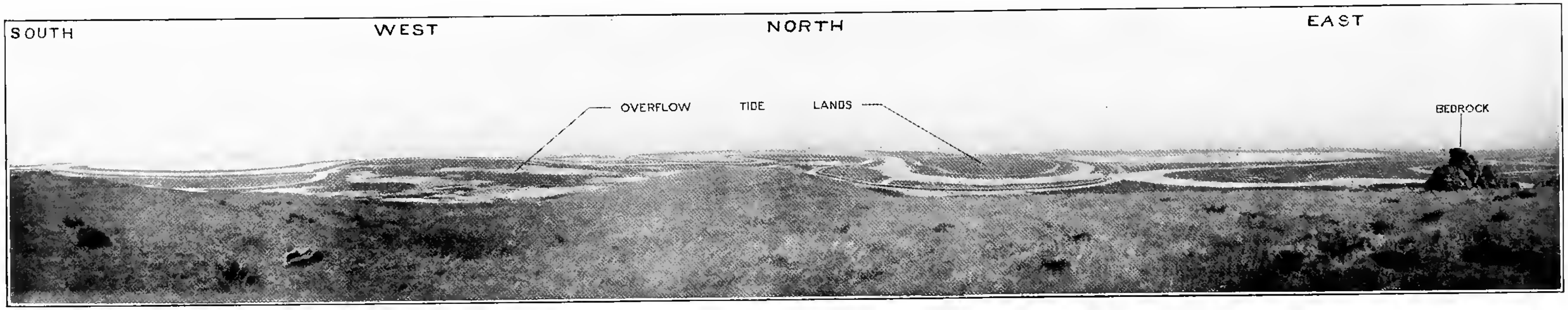
Dr. Branner defines the Niles Cone as follows: "This area forms a triangle, having the mouth of Niles Canon at its eastern apex, the town of Newark at the southern apex, while the northern apex is about one mile northeast of the town of Alvarado.

It should be noted, however, that while there can be no serious question about the underground waters of this area coming from the Niles Canon, as the distance from Niles increases, the difficulty of proving that the underground water actually comes from that canyon increases proportionately."

A strip marked "Doubtful" by Dr. Branner rises in a small tule pond half way between Niles and the Lagoon from which it parallels and adjoins the southerly leg of the triangle and has a width of one-half to three-fourth of a mile.

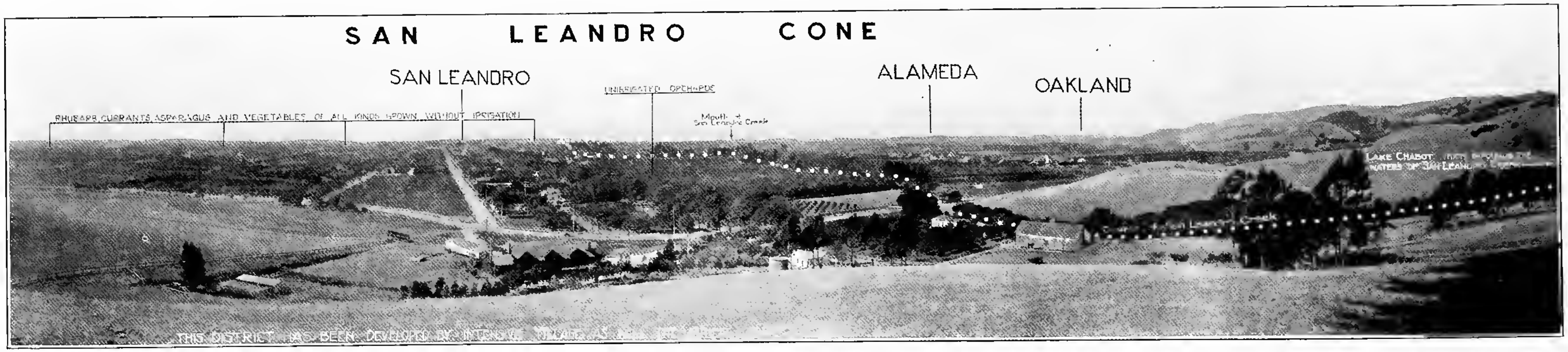
Referring to Page 109 of Mr. Freeman's report, he says: "In the present instance we were fortunate in securing the aid of Dr. J. C. Branner, Vice-President of Stanford University, than whom there is no one with more profound knowledge concerning the geology of the region, etc., etc." In spite of Mr. Freeman's high regard for Dr. Branner's knowledge, he accepts without question Mr. Dockweiler's report on the area of the Niles Cone and Mr. Dockweiler's figures on the water requirements of this area. Dr. Branner's report on this region and the boundaries marked by him, include 8860 acres, while Mr. Dockweiler covers the entire area between the bay shore at the edge of the tide lands from the outlet of Mowry's Slough on the south to a point half way between the mouths of Alameda and San Lorenzo Creeks on the north, or 47,360 acres. To anyone familiar with the territory and with the slightest knowledge of geology the fallacy of Mr. Dockweiler's contention must be self-evident. The Coyote Hills, consisting of a ridge from 100 to 300 feet high with frequent outcroppings of rock, extend from the edge of the tide lands near Mowry's Slough to about one mile south of Alvarado, thereby cutting off any connection of Alameda Creek with these tide lands. Even Mr. Dockweiler did not have the boldness to include these hills in the cone area and, therefore, he deducts them, but he does not explain how Alameda Creek was able to perform the hydraulic gymnastics of forming the twelve to fourteen thousand acres of tide land adjoining this five mile stretch of hills on the west, unless he considers that the prehistoric winter floods were able to float these massive hills to their present position. (Plate page 274.)

Referring to the accompanying photographs of the Niles Cone, as shown on Page 203 of the Freeman Report, the point from which this panorama was taken is one mile south of the apex of the cone. It gives the impression that the foreground, the most fertile part of this region, which is unquestionably in the cones of Mission Creek and other small streams to the north, is within his boundaries. From the observation of the writer it appears that the limits of the Niles Cone, as described in the city's report, were drawn with a bold free hand and without any



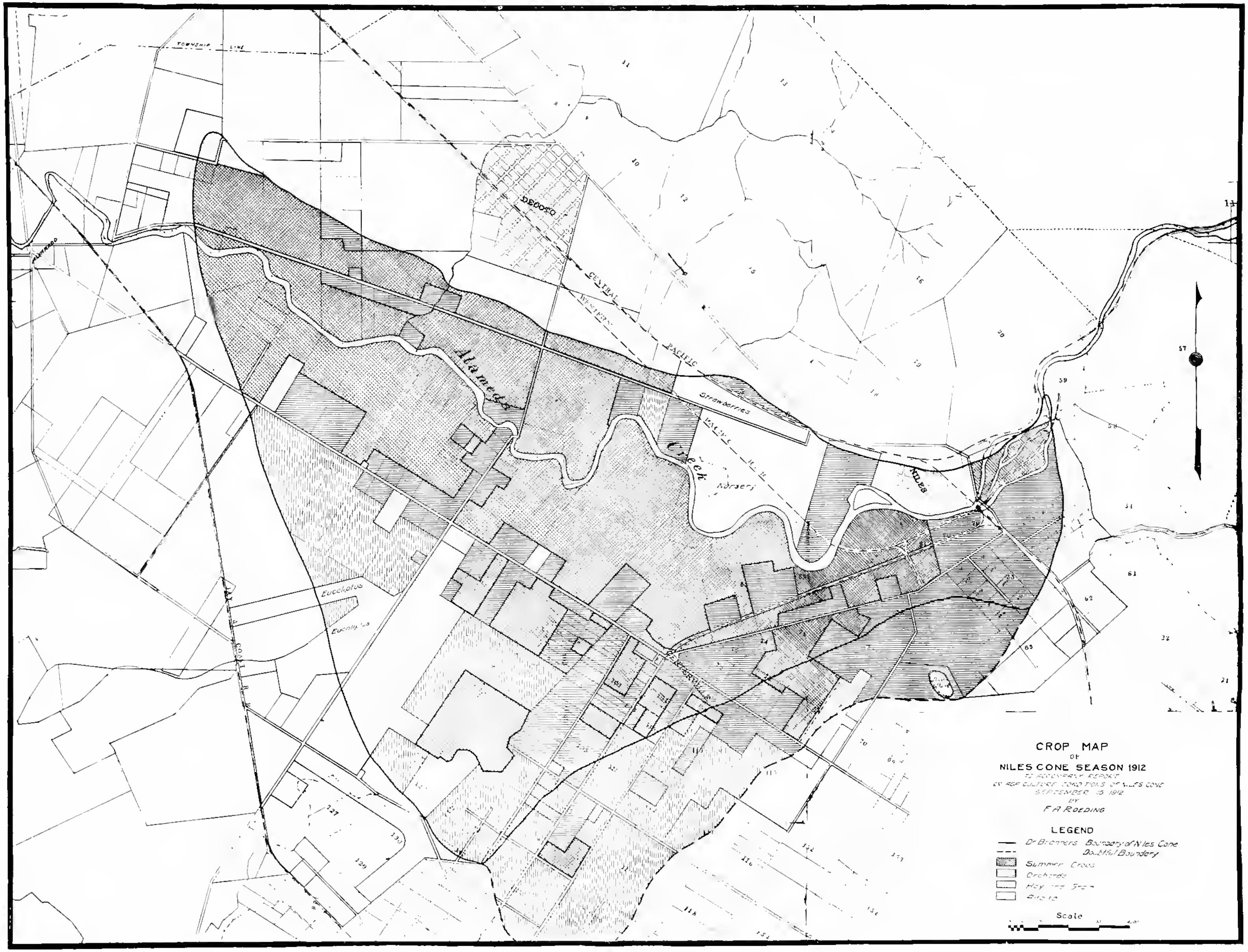
TIDE LANDS OF ALAMEDA CREEK.

Panorama of swamp and overflow lands from the top of the most northerly of the Coyote Hills. This large area is used by salt works to produce salt.



A REGION OF UNEXCELLED "INTENSIVE FARMING."

This highly productive district is not irrigated, its water supply having been impounded by the Lake Chabot Dam for 37 years. Intensive farming is developed to the highest degree. The dotted line indicates the course of San Leandro Creek and gives evidence as to the size of the cone. It is worthy of note that this creek is also the boundary line of the City of Oakland. The Niles cone will soon be part of a great city.



CROP MAP NILES CONE.
Showing that practically the entire area of the cone outlined by Dr. J. C. Branner consists of non-irrigated crops.

A SPLENDID CROP IN A DRY YEAR.

Tomatoes raised without irrigation on the former Overacker Place in the center of the Niles Cone. Crop estimated at 12 tons per acre. View taken October 14, 1912, after an unusually dry year. The demand of canners is for unirrigated tomatoes.

investigation either of the topography or the geology of this region. Dr. Branner's boundaries, however, follow well defined geological deposits and elevations in the contour, the base of the Cone being in a territory where the Coyote Hills had a marked influence on the alluvium deposited by Alameda Creek, and this Dr. Branner has called *"doubtful territory."*

Attention is called to the greatly exaggerated limits of the cone as defined by the City's representative. (Plate page 260.)

It is claimed that this region would be rendered absolutely unproductive if the Spring Valley Water Company should carry out its plan of further diversions from Alameda Creek, despite the fact that irrigation is not and never has been a general practice and never will because of climatic conditions and characteristics of the soil, even though the water table be far lower than at the present time.

In order to prove this assertion a crop survey of the cone area was made, corresponding with Dr. Branner's limits, and the crops grown thereon are shown on the accompanying map, the acreage of each crop being approximately as follows:

	Acres
Orchards	2,050
Summer Crops, including tomatoes, potatoes, beans, peas, corn, beets and vegetables	4,200
Eucalyptus plantings	45
Alfalfa	600
Grain and hay	1,300
Pasture and waste	20
Nursery	480
Town sites	115
Strawberries	50
	8,860

DESCRIPTION OF CROPS.

Orchards.

Orchards are mainly in the district around and between Niles and Centerville. Apricots form about 60% of the trees, cherries 20%, and assorted fruit, such as prunes, plums, apples, pears, almonds, walnuts, peaches, etc., the remainder. This region, on account of its mild climate and little danger of late frosts, is particularly well adapted to the growing of apricots and this has been a profitable crop for many years past. Cherries also find the Bay region more congenial than the other parts of the State and the trees are longer lived in this section, although the cost of picking and the necessity of disposing of them while fresh makes their culture less popular than that of the apricot. The other fruits enumerated are principally grown in family orchards, although the Ellsworth orchard, near Niles, is largely devoted to prunes, and there is a young walnut orchard of about thirty acres between Newark and Alvarado.

Summer Crops.

Of these crops tomatoes occupy the leading place, with possibly 1500 acres. Peas, corn, potatoes, beets, beans and vegetables follow in the order named. All of these crops require intensive cultivation and the rich alluvial deposits upon either side of the present channel of Alameda Creek, as shown on the accompanying map, are principally devoted to this purpose. The farmers are largely Portuguese and many of them have become well to do, beginning as tenants and finally buying the lands they farmed with the profits made from them. That so large an area of these valuable lands should be devoted to summer crops instead of to orchards speaks well for the profits derived from them. It is self-evident that in handling them as they do the farmers are securing the greatest returns. In some cases it is possible to secure two crops in one year, as with peas and potatoes, or peas and corn.

Eucalyptus Planting.

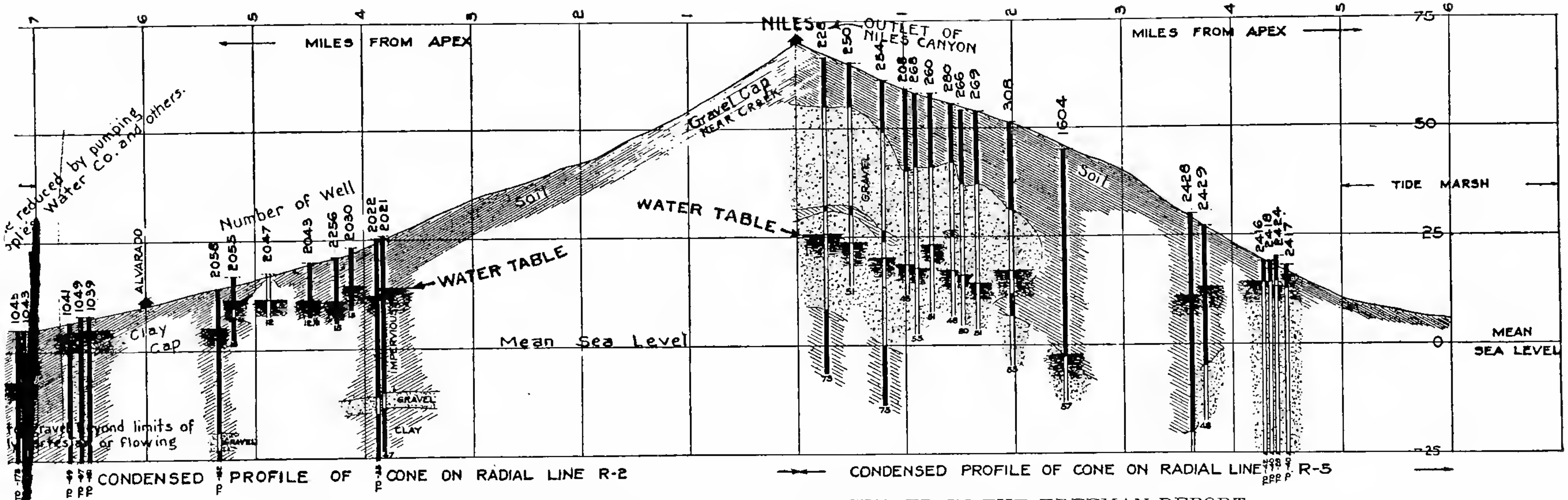
It is not strange that a disciple of the eucalyptus boom should also be found in this fertile region, and that he is still an enthusiast is shown by very recent plantings. Without discussing his wisdom in devoting lands suitable for many profitable crops to these trees, it may be stated that they are making rapid growth and the older plantings have formed dense forests of considerable height.

Alfalfa.

The region near Newark seems to have gone into alfalfa-growing more heavily than any other section within the area, due to the large dairies on the edge of the tide lands. Although this is nearly always an irrigated crop, not over 10 per cent. here is artificially watered at the present time, and of the 90 per cent. unirrigated about one-half will produce six or seven crops this year. The best of these unirrigated alfalfa

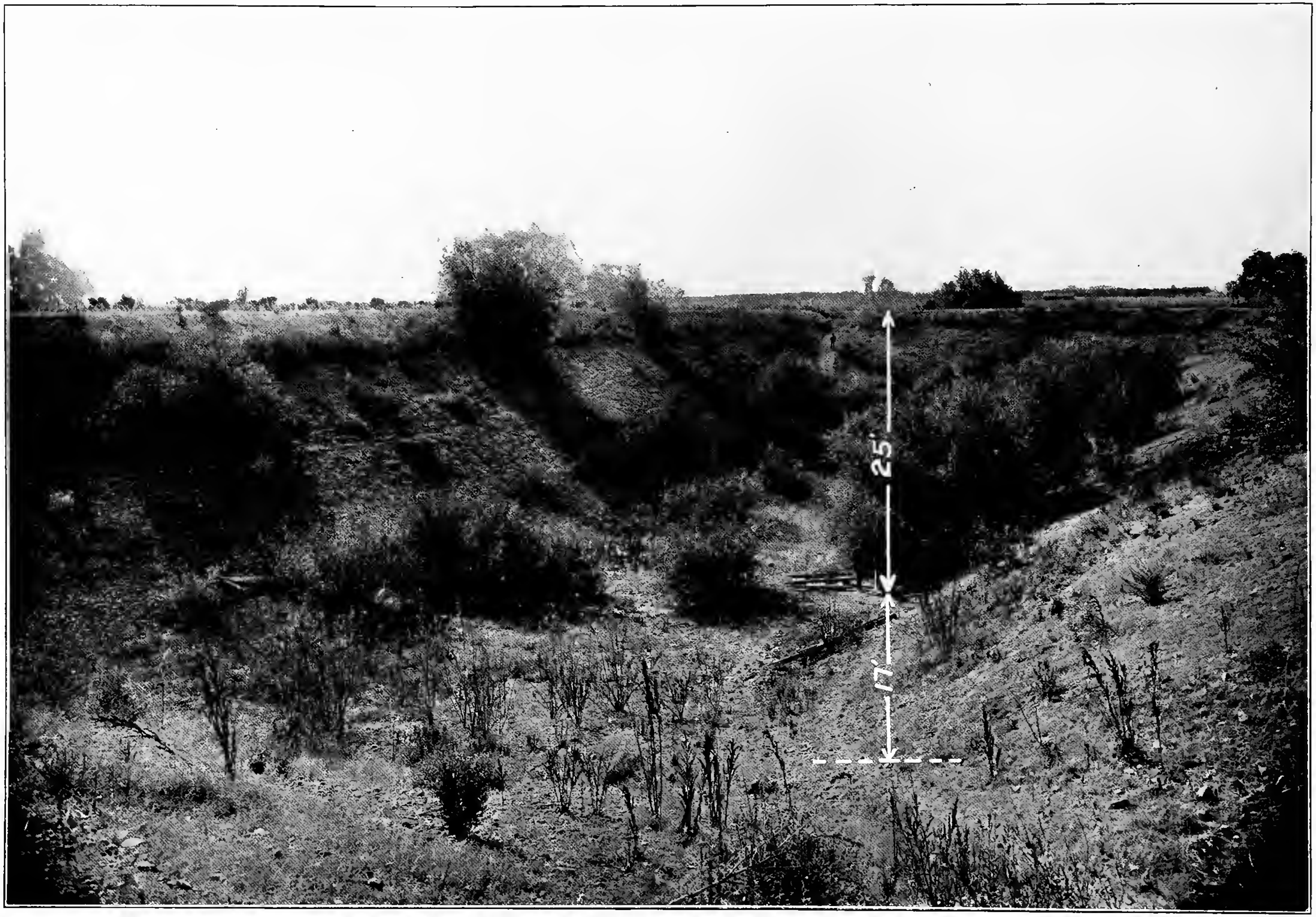
UNIRRIGATED SUMMER CROPS, NILES CONE.

Unirrigated Tomatoes With Corn, Summer Squash and Other Vegetables, All Unirrigated, in the Background. Taken on Land of E. H. Dyer (Bell Ranch) Near Decoto. Note Dry Bed of Alameda Creek on the Right 25 Feet Below the Farmed Land, too distant from the Surface to Aid in the growth of Summer Crops.



THE WATER PLANE OF THE NILES CONE AS PRESENTED IN THE FREEMAN REPORT.

Mr. Freeman's representation (page 95) of the water plane about July, 1912. In spite of a depth throughout the intensively farmed portion of more than 30 feet, orchards and crops of all kinds produced well without the addition of water by irrigation, although 1912 is recognized as being a very dry year. This condition prevailed during the growing season. Note particularly the great distance of the water plane from the surface.



DEEP CUT ON OVERACKER PLACE NEAR CENTER OF NILES CONE.
Note the distance (42 feet) from the ground surface to the water plane.

fields follow a strip of land along the easterly side of the county road from Decoto to Newark westward from the Centerville-Alvarado county road to the edge of the tide lands. There is every evidence that one of the former channels of Alameda Creek is here and owing to the slight elevation above tide, this land has always been moist and always will be. Occasional willows are still growing on this land and doubtless it had to be cleared in order to plant alfalfa.

Grain and Hay.

The lands east and southeast of Newark and those along the base of the cone, although suited to other crops, seem to have received little attention in their development, and it is here that we find the bulk of the grain and hay farming. With the subdivision of these lands and their sale in small parcels, more intensive cultivation will follow, and it is safe to predict that as this section develops the greater portion of them will be devoted to summer crops and alfalfa-growing.

Pasture and Waste Land.

Outside the bed of Alameda Creek all waste and pasture land lies near this channel in the vicinity of Alvarado. A short distance east of Alvarado, this creek is more or less on a level with the surrounding country and forms a wide delta, a considerable portion of which is farmed this year, a fact made possible only by the absence of floods this past winter. In a year of normal rainfall this land is overflowed during the winter months and remains wet until so late in Spring that very little of it can be farmed. North of this channel and just outside the extreme northerly corner of the cone, the land is so alkaline that it cannot be farmed.

Nursery.

The California Nursery Company owns about 600 acres adjoining Niles on the west. This area is not entirely planted to nursery, as fifty acres have been leased for strawberry culture, and as nursery stock makes an unusually heavy draft on the soil it is necessary to vary the crop so that at the present time there are possibly 400 to 450 acres in actual nursery, including variety orchards, the balance being planted to annual crops.

Town Sites.

Only the business portions of the towns of Niles and Centerville are included in the area. The residences comprise from one to three or five acres each and in this report have been treated as small farms, their acreage being summed with the orchards.

Irrigation and Water Requirements of Crops in This Region.

SUMMER CROPS.

The present season has been a most severe test on the growing of crops without irrigation and the results obtained are a high tribute to the farmers of this and adjacent sections. Summer crops, which cover nearly one-half of the area of the cone, have received no additional moisture outside of the rainfall (with the exception that tomatoes when transplanted to the open ground are always given about one quart of water to each plant) and their growth shows no effect of the drought. By cultivation, the moisture can be retained in the soil and the well-kept condition of all fields of summer crops testifies to the knowledge of the farmers in this respect.

Plates on pages 264 and 266 show tomatoes grown this season without irrigation on the former overacker place, near Centerville, and on land of E. H. Dyer (Bell Ranch), between Centerville and Decoto. On the former the water table was measured in a well on the property and showed elevations throughout the season far below the reach of rooots.* The plate on page 266 shows the dry bed and steep banks of Alameda Creek at the edge of the tomato patch with corn. summer squash and var-

*(Plate No. 1.)

Height of water table during 1912, as measured from ground surface in a well on the former Overacker Place, near Centerville, showing that excellent summer crops and orchards have thriven without irrigation, although the water table was far beyond the reach of plant growth.

Date 1912		Feet	Date 1912		Feet
Jan.	2	36.7	June	1	35.3
"	16	36.9	"	15	36.2
Feb.	1	36.0	July	2	37.2
"	15	35.2	"	16	37.75
Mar.	2	35.2	Aug.	1	38.4
"	16	34.15	"	15	39.65
"	26	32.66	Sept.	3	40.1
Apr.	2	32.8	"	17	40.65
"	16	33.1	Oct.	1	41.0
May	2	33.3	"	12	42.2
"	16	34.1			

UNIRRIGATED APRICOT TREES.

Unirrigated apricot orchard (6 years old) on the former Overacker Place near Centerville. The roots of these trees have never been within reach of the water table shown in plates accompanying. View taken October 14, 1912. No signs of drought after the dry season. New growth of this season indicated in picture.

ious vegetables growing in the distance. The banks of Alameda Creek at this point are twenty-five feet high and the soil is a fine silt mixed with sand and is naturally well drained. None of these crops has been irrigated and their growth shows that they need no irrigation. Tillage alone has maintained the winter's moisture in the soil and even though the rainfall this past season was below normal good crops were grown on this well drained soil. The business of farming, as it is being recognized at the present time, is first to maintain the fertility of the soil by rotation, fertilizing, etc., and then to produce adequate and profitable crops with the smallest outlay. Irrigation means an initial expense of from $10 to $50 an acre under large gravity systems, while with individual pumping plants the expense is much greater and increases in proportion as the area decreases. Outside the initial cost of water, there is land to be leveled, ditches to be built, surface irrigation pipe to be purchased, the cost of fuel, etc., ditch assessments and the labor of irrigating. Where the rainfall is sufficient to produce various good crops and the climate is favorable, it stands to reason that the additional expense of irrigation will be viewed by the farmers as a matter of dollars and cents, and if they are making satisfactory returns with Nature's provision of moisture they will not greatly increase the cost of production by artificial irrigation when the additional returns will not justify such cost.

In climates and soil conditions far less favorable, and with a rainfall of one-half to three-quarters that of the Niles region, there have been ample demonstrations in the past five years that good crops can be grown by careful and proper tillage that will conserve the rainfall. The annual sessions of the Dry Farming Congress, made up principally of farmers throughout the great American Desert, testify to the results which have been obtained and the great interest which is being developed in this important branch of agriculture. Not only summer crops, such as potatoes, peas, beans, corn, beets and grain of all kinds have been grown on the dry, wind swept prairies of Wyoming, the Dakotas, Colorado, New Mexico, Western Nebraska and Kansas and the Panhandle and Western Texas, but there are a number of orchards throughout this region that have never received a drop of irrigation water and are thrifty and producing crops.

Orchards.

Of the orchards within the boundaries, only three were found in which actual irrigation had taken place, viz.. those of J. C. Shinn, Mrs. Tyson and F. A. Donley, totaling only about 100 acres. J. C. Shinn has probably the oldest orchard in this district and as a former large owner in the Washington & Murray Township Ditch he has always used water for irrigation. For this reason the roots of his orchard trees are close to the surface and it is more than likely should he discontinue the practice that his trees would suffer. In the second instance berries are growing among the orchard trees, while F. A. Donley is endeavoring to interest farmers in electrical pumping plants. As the bulk of the orchards are apricots and cherries, both ripening early in the year, they would not require water, especially when the tillage of the soil is so well maintained. However, with cheap electric power, pumping plants are being installed in a number of orchards and it is quite likely that many of the orchardists may adopt irrigation as a means of increasing and insuring their crops in dry years, although the additional cost with no apparently additional results may deter many from installing or using their pumping plants in a normal year. As an illustration, an apricot orchard on the banks of Alameda Creek near Centerville (Plate page 270) may be mentioned. This orchard is six years old and has never been irrigated. The land is well drained and is approximately twenty-five feet above the bed of Alameda Creek. In this year the water table, as recorded in a well on the property, stood at heights shown in the table, Plate No. 1, on page 269, at various times during the year and was, therefore, always beyond the reach of the roots. The trees, as shown by the photo taken October 14th. have made a growth of from four to six and seven feet this season, and at the time the photograph was taken they showed no sign of any lack of moisture.

Strawberries.

The strawberry plantings already referred to, on land of the California Nursery Company, are of interest in their water require-

FLOODS AT ALVARADO.

A frequent winter scene. The inundation of great tracts of fertile lands, preventing their tillage, by the waste waters of Alameda Creek, which have passed over the Niles Cone. A lost natural resource. Taken in a season of about normal rainfall.

ments as furnishing a basis of what would be needed, provided this crop were extensively grown in the cone limits. Driscoll Bros., who are the owners of these strawberry patches, have for some time been interested at Watsonville in the same industry and are, therefore, experienced in their culture. Their representative maintained that it was necessary to irrigate every third day during the summer months, extending from about May 1st to about October 15th. They operate an electrically driven No. 6 certifugal pump for about ten hours each day, irrigating about 16 acres, which would mean 1½ acre inches per acre per irrigation, or roughly six feet in depth over the surface per season. As the ground is never allowed to dry out the quantity required for each irrigation is correspondingly small. It is very questionable whether this area of strawberries will ever be increased in this district as this commodity is very perishable and must depend entirely upon local consumption. Furthermore, the Watsonville district is somewhat earlier, thereby getting the higher prices, and the summer climate of the Pajaro Valley is cooler and more subject to fogs, so that its production during the season is heavier.

Alfalfa.

Alfalfa comes next on the list of crops requiring irrigation. No account is taken of small patches of fractions of an acre to one or two acres, which are included in many of the house lots and are sprinkled by hose. Mention has been made that only 1.6 per cent or 100 acres of the total area in this crop are irrigated. The best field is that under lease to Sam Aftergut & Co., near the junction of the Centerville-Alvarado and the Decoto-Newark county roads. This field contains 34 acres and is irrigated by two 4-inch Caton centrifugal pumps and portable gasoline engine. The land is very uneven and both slip-joint pipe and canvas hose are used. Each pump has a capacity of 600 gallons per minute and in a day of eleven hours three acres can be irrigated by each. This field has been irrigated three times this year and five crops have been cut. There will be another crop this fall but it will not need irrigation. According to the above figures, this land has required 1½ acre feet per acre for the season and results were excellent. In fact, this field is as good an alfalfa field as can be seen anywhere in the State.

J. B. Rose, near Newark, has some 50 acres planted to alfalfa with a No. 8 centrifugal pump and 15-horsepower electric motor. No record is kept of water pumped or area irrigated, which is by means of slip-joint pipe, but pump is run almost continuously during the three summer months, provided the power is not shut off. This field is not as well handled as the first mentioned and it appeared as though the water used could have been employed better and more systematically on a much larger area, as part of the alfalfa plantings were suffering severely for water and did not appear to have received any during the season.

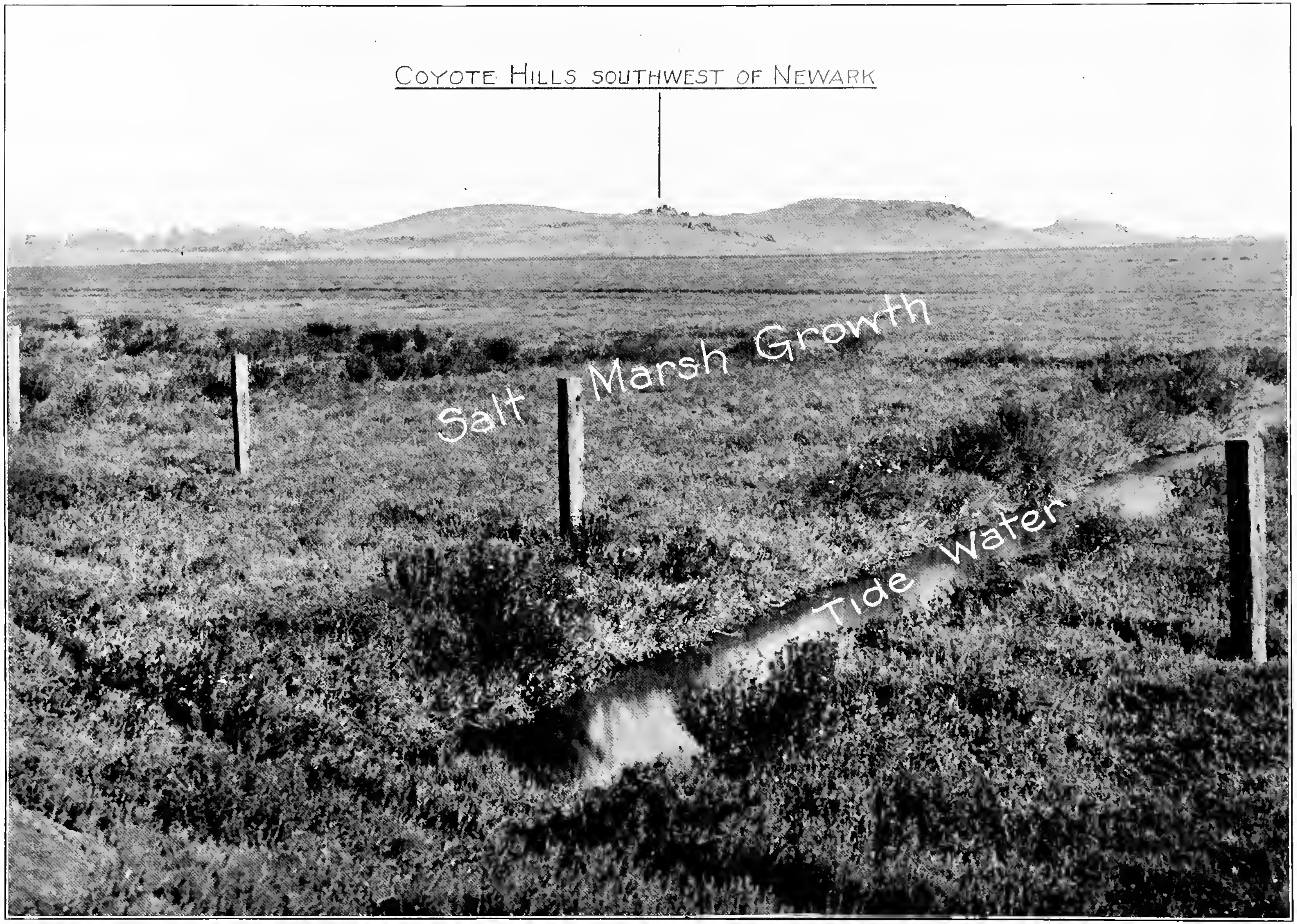
Other irrigated fields were those of C. H. Patterson and one opposite the former Beard property on the Centerville-Alvarado county road, but both fields are small and no data could be obtained. F. H. Sayles, near Newark, is at present installing an irrigation plant for his alfalfa field, which will be ready for operation next season. The most remarkable fields are those already mentioned near Newark, which follow a probable former channel of Alameda Creek. These fields looked even better than some of the irrigated ones and six crops had been cut on many of them this season. However, gophers are destroying so many of the plants that many of the farmers talk of irrigating for the sole purpose of destroying these and other rodents. The limits of this strip of land are well defined by the growth of the alfalfa, as inside the limits the plants are a bright, healthy green and vigorous, while outside they are stunted and dry.

Eucalyptus.

The one grove already mentioned, on the C. H. Patterson land, has received no irrigation since planting. The ground between the young trees is kept in a high state of tillage, as in an orchard, and apparently this is maintained until the trees become too large.

Grain and Hay.

These crops are obviously not irrigated and it is a matter of only a short time when large fields of cereals will give way on these and similar high priced lands to crops of higher productive value.



THE BARRIER.
The Coyote Hills between Newark and Mowry's Slough cutting off the south end of the greatly exaggerated Niles Cone (Freeman report) from the tide lands.

Tide Lands.

As one of the City's Engineers in his report refers to tide lands and their reclamation by irrigation, the writer took occasion to visit these tide lands between Alvarado and Newark, although outside of the Niles Cone. The ownership of the larger part of these tide lands is held by large corporations and they are used for the production of salt and show that this is and will be their most valued product. Over 10,000 acres between Alameda Creek and Newark Slough belong to three salt companies or their associates, and it is unlikely that the reclamation of these tide lands will take place as long as these lands can be used for the production of salt.

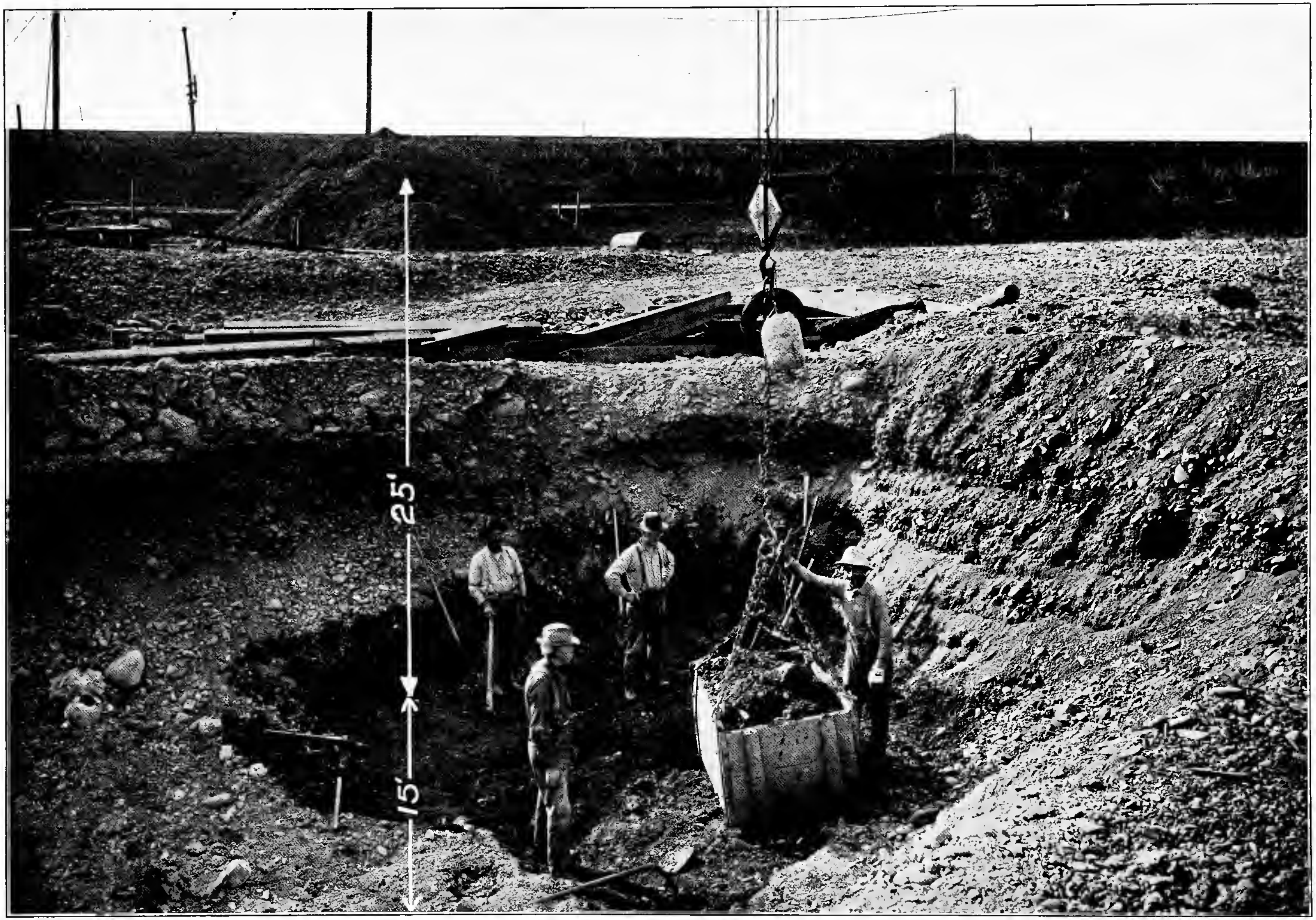
On Page 204 of the Freeman Report it is asserted that about 1500 acres of tide lands have been reclaimed to date in his grossly exaggerated boundaries of the Niles Cone, giving the impression that these lands were similar to those shown in the panorama view (Plate page 260). As a matter of fact, this area is at the edge of the actual tide lands and was affected only partly by the highest tides, so that reclamation, both on account of the absence of sloughs and the freedom from overflow of salt water during the greater part of the year, was a very simple matter. Of the lands which are covered daily by the tides practically none have been reclaimed and there is little prospect that they will be.

Although one engineer for the City refers to the interesting experiments carried on by Mr. Oliver, he has failed to give any statement of the cost of reclaiming salt marshes, and this will be found to be commercially prohibitive. Aside from the expense of levees, the filling in of small sloughs, leveling the land and irrigating it for three or four years, or even two years, without any returns, there will always be a yearly expense for the maintenance of levees. Even should this reclamation be successfully handled, and the land be placed in condition for crops, it is a self-evident fact that only summer or shallow-rooted crops will be grown. As already shown, these require no irrigation, provided the soil is properly tilled so as to yield the largest and quickest returns with the least expense, the ideal condition for any business or farm. The statement of a city's representative that these marsh lands, if reclaimed, will require water for irrigation is therefore misleading, as such irrigation will only be required during the period the salt and alkali are being leached from the top soil. It is also a mistake to incorporate such an area as reclaimable, for the reason that a large portion of these lands will be found to contain such high percentages of lacustrine clay that the percolation of water through them, which is absolutely essential for the leaching process, is impracticable for reclamation of commercially productive acres.

IRRIGATION FROM TUOLUMNE RIVER AND FROM ALAMEDA CREEK COMPARED.

High Duty in the Modesto-Turlock Districts.

Referring to Appendix 17 of the Freeman Report, in the matter of the irrigation requirements of the Modesto-Turlock Irrigation Districts, *whose water supply has the same source as the proposed Tuolumne River project,* great pains have been taken to show the excessive use of water in the districts, and conclusions have been drawn that when the entire area is developed, the duty of water is to be two and one-half acre feet per acre, although "examination of the local conditions show that *a duty of 1½ acre feet of water per year* should be sufficient as an average." There is also presented the curious argument that when 2¼ acre feet per acre are applied annually upon the 206,000 acres in the districts 51,620 acre feet of water will have to be pumped *annually* by the districts to keep the ground water ten feet below the surface, this water to be used for further irrigation. No account seems to be taken of the requirements of plant life when the entire area is developed and irrigated, as the argument seems to be based upon the use during 1911 when irrigation was practiced on only one-half the area. If Mr. Freeman had cared to explain the excessive use and the present high water table in the districts he would have been to no great trouble to do so as he doubtless knows the very sandy character of the soil throughout a large part of both districts; that the ditches have been filled to their capacity since water was first turned into them; and, furthermore, that the seepage losses in these ditches have been and still are very large.



EXCAVATION AT NILES FOR PIERS OF NEW COUNTY BRIDGES.
Dry floor of excavation 25 feet, water table 40 feet below farmed area as indicated by arrows.

The annual rainfall is stated by the report to be ten inches and the mean annual temperature 63.9° No mention is made of other important climatological data, viz:—The summer temperature is high, the air is dry, while the cold of winter is greater than in the bay regions. Until irrigation was introduced this area was a sea of waving grain in the spring months and dry, parched stubble fields during the summer and fall. No attempt was ever made to raise summer crops, orchard trees or alfalfa on these sandy plains without having the necessary water for irrigation.

Low Duty in the Niles Cone.

In the Niles Cone with an almost uniform mean daily temperature throughout the year, with summer fogs, with a soil highly retentive of moisture when tilled, and where crops of all kinds have been grown for many years solely under an average annual rainfall of 20 inches, or double that of the above mentioned districts, *here* it is suddenly discovered by the engineers of the city that water to the extent of two acre feet per acre will be required (See Page 204 Freeman Report) to prevent 80% (?) of that vast Niles Cone area from becoming a barren, uninhabitable waste.

Why is Mr. Freeman so frugal with these irrigation districts where no one can question the need of irrigation and where the rapid development now going on will in a few years place highly cultivated farms on every acre included in their boundaries, while in the Niles Cone he finds there will be need for almost the same duty of water? Accordingly the Niles Cone would require annually 2 acre feet for irrigation plus 20 inches of rainfall or a total of three and two-thirds acre feet of moisture per acre, while the Modesto-Turlock Districts need only two and one-half acre feet for irrigation plus 10 inches rainfall or three and one-third acre feet. Why does Mr. Freeman place the water requirements of the Modesto-Turlock Districts with a dry hot climate at one-third an acre foot per acre less than in the humid climate of the Niles Cone?

Among other misleading facts of the Freeman Report are a number of photographs on Pages 92 and 93, showing irrigated areas, all alleged to be within the Niles Cone, and giving the impression of the extent to which this practice has been carried.

Two pictures are shown of *"Irrigation on the Bell Ranch, 185 acres in truck products."* Of this 185 acres, S. Morimoto, one of the tenants, irrigated only 20 acres in tomatoes and vegetables (the only tomatoes irrigated in this section), which is the photograph shown. Ben Massei, another tenant, irrigated 10 acres in vegetables but the balance of 155 acres received no irrigation whatsoever, although as correctly stated the entire area was in truck products. Attention is called to Plate on page 266 of this report, "Tomatoes on land of E. H. Dyer (Bell Ranch)", showing the unirrigated portion.

California Fruit Canners' Association,
120 Market Street,
San Francisco, October 30, 1912.

Mr. S. P. Eastman,
City.

Dear Sir:

With regard to tomatoes grown on irrigated land as compared with those grown on non-irrigated land, there can be no question but that in a normal season the latter will be preferred for canning purposes.

In a dry year, such as that through which we are now passing, *some* land in Alameda County, which would ordinarily bear superior tomatoes without irrigation, has suffered from the drought and yielded a product inferior to tomatoes grown under irrigation. Ordinarily we get a better product from Alameda County from non-irrigated land than from any other district.

Yours very truly,
M. J. FONTANA,
General Superintendent.

J. K. ARMSBY & CO.
October 28, 1912.

Dear Sir:

I beg to advise you that in purchasing tomatoes for canning purposes, canners, as I understand the matter, always give preference to tomatoes raised on unirrigated soil, as tomatoes so raised carry a smaller percentage of water than is the case with tomatoes raised on irrigated soil,

Yours very truly,
GEORGE N. ARMSBY.

S. P. Eastman, Esq.,
Spring Valley Water Co.,
San Francisco.

(A similar letter from the Central California Canneries Co. was also received.)

Two views, on opposite pages, are of irrigation of nursery stock by the California Nursery Co.

"*600 acres.*" It should be noted that these small trees are receiving water furnished by the Spring Valley Water Co. No illustrations are shown of older trees being irrigated, nor is any explanation given, that the actual area in nursery stock is not more than 480 acres, for if the entire property were planted, where would the ground for the next season's planting be?

Three photographs are reproduced, two on one page and one on the opposite page, of the strawberry farm, which is part of the 600 acres of the California Nursery Co., although the report has overlooked stating so.

Irrigating alfalfa on the Gregory Ranch, Decoto, gives the impression of vast areas. This ranch has been subdivided and sold years ago, and what is shown consists of one of the five-acre subdivisions. Both this and the one remaining view are outside the Niles Cone boundaries. Acknowledgement must be made that irrigation scenes are scarce in this region, and the City's Report deserves high commendation for having succeeded so well in securing these views.

Under the caption, "The Niles Cone Needs This Water for Irrigation," on Page 94 of the Freeman Report, he says: "If two feet duty or net depth of water per year over the surface of the land is required, which is the minimum we have assumed for Turlock and Modesto under a *less intensive kind of farming,* this would call for, etc., etc., 26 billion gallons per year, chiefly in the growing months." What is Mr. Freeman's conception of *intensive kind of farming?* Why is the duty of water in Southern California the highest in the United States if *this intensive kind of farming* does not conserve the scant supply? Why has *intensive farming* been preached by renowned writers on agricultural subjects for centuries, and why is it now the basis of the most important investigations of the United States Department of Agriculture, if not to conserve the moisture in the soil for plant growth and increase the duty of water, whether by irrigation or rainfall? Does Mr. Freeman know that the Niles Cone today would be producing nothing but hay or grain if it were not for this *intensive kind of farming?*

Intensive farming means stirring the soil surface so thoroughly that capillarity will be broken and the moisture conserved as much as possible for the use of the plant, so that it may not be wasted by evaporation from the surface, and it is thus possible to grow more valuable products. Experiments of the United States Department of Agriculture, carried on by the writer while in that service, showed that with a dry, pulverized soil ten inches deep overlying a moist soil, there was no evaporation loss, the loss increasing gradually with lesser depths of mulched soil, while with an uncultivated soil all moisture was quickly lost. The greater the tillage the smaller the loss by evaporation.

Agriculture in the San Leandro District.

For comparison, the productive San Leandro Cone which is in the drainage of the San Leandro Creek, was also studied and examined. The upper drainage of this creek is impounded in the Lake Chabot Reservoir, which was constructed in 1874-5, and, therefore, this district is taken as a fundamental parallel of the condition in the Niles Cone, when the development of the Spring Valley Water Company is carried out. No water was wasted over this dam in the years 1907-1908, 1909-1910, 1911-1912, while the waste from 1901 to 1912 inclusive, a period of eleven years, amounted to 11 M. G. daily, as against 14.6 M. G. daily which the Spring Valley Water Co. proposes to waste over the Sunol dam.

Mr. Freeman proposes to increase the height of the Chabot dam and thereby store more of the flood waters of San Leandro Creek, although he recognizes the needs of the San Leandro Cone for a portion of these waters and is willing to concede a sufficient flow to protect this region from the devastation which is predicted for its southern neighbor. But it is evident that Mr. Dockweiler did not figure the area of this cone as he did the Niles Cone, for had he done so the entire flow of this creek would now be required to meet demands for irrigation and domestic supply as well as reclamation of its tide lands.

This district, extending from where the creek leaves the foothills to a point about one mile west of San Leandro, where the channel turns to the north near the edge of the tide lands, is without doubt the most *highly developed agricultural land in the northern portion of the state.* Orchards of cherries and apricots, which

cover possibly one-fourth of the area, are kept in a high state of cultivation, while the other three-fourths are devoted to summer crops, berries, rhubarb and asparagus. The soil is a black adobe on the lower portion, shading to a clay loam near the hills. If irrigation is practiced anywhere throughout this district, it is on such isolated areas as would require a house to house canvass and would then possibly be found only in one or two small orchards. The berries, which are mostly currants, and the perennial plants, rhubarb and asparagus, are not irrigated anywhere in the district, while summer crops, as in the Niles Cone, require no irrigation and yield returns which pay a good interest on the high values placed on this property ($800.00 to $1200.00 per acre).

The soil is so productive under the splendid method of *intensive tillage* that even the land between the orchard trees produces large crops of commercial leguminous plants, and the rights of way of both the Southern Pacific and Western Pacific railroads not occupied by the tracks are yearly farmed to rhubarb, beans, peas, corn and other high class products.

CONCLUSION.

Agricultural Future of the Niles Cone.

The growing of crops in the Niles Cone, on account of the high valuation of the land, will always be confined to products bringing the largest returns with the least expense, the foundation of any business. It is an undeniable fact that summer crops, such as potatoes, beans, peas, corn, tomatoes and vegetables, with currants, raspberries, rhubarb, etc., can be grown under the most favorable conditions with the rainfall alone and with returns most commensurate with land values, made possible by the earliness of this district and its close proximity to large centers of population.

The westerly and northwesterly portions of the cone are overlayed by a thick clay cap, rising toward the surface two miles up Alameda Creek from Alvarado and dipping deeper westward. Does Mr. Freeman contend that the roots of plants penetrate this thick cap of clay to find their way to water below it?

Does Mr. Freeman desire to deny the fact that excellent crops of all kinds have been grown without irrigation throughout this district for a good many years on the well drained lands along Alameda Creek, where the water plane is anywhere from thirty to fifty feet below the level of the ground surface during the critical periods of plant growth (those of flowering and reproduction) and therefore far below the reach of the roots? This district is in a very high state of tillage and is producing per acre as large a net profit as any lands in the State.

The record of the well on the former Overacker property (the center of the cone) during a period of years, as shown in the following table, is ample evidence of the ability of this district to produce crops without irrigation, no matter where the water table is located.

Height of water table, as measured from ground surface in a well on the former Overacker Place, near Centerville, during the normal year 1910, the wet year 1911 and the dry year 1912.

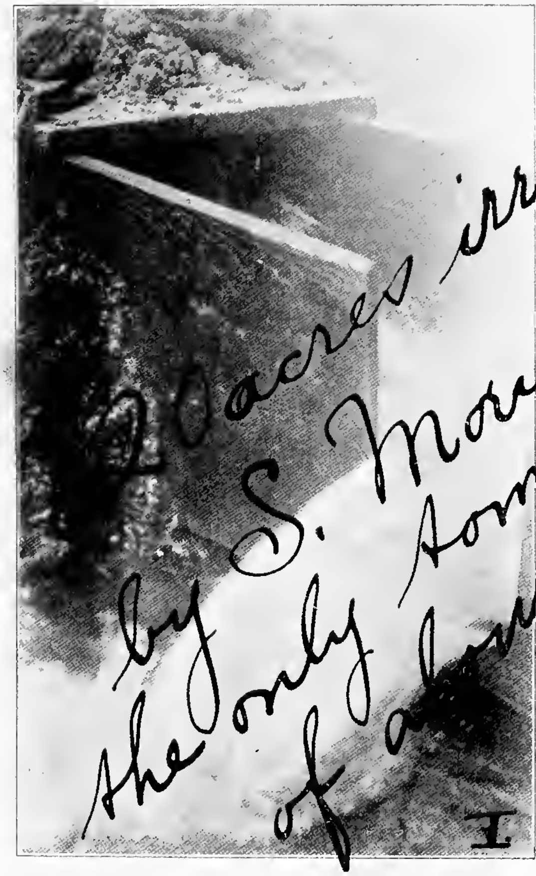
Date 1910	Feet	Date 1910	Feet
Sept. 17	37.07	Nov. 16	39.53
Oct. 1	37.99	Dec. 3	39.91
" 15	38.62	" 15	40.24
Nov. 2	39.16		

Date 1911	Feet	Date 1911	Feet
Jan. 3	40.87	July 1	27.24
" 19	34.66	" 15	27.91
Feb. 1	27.74	Aug. 1	28.99
" 14	26.24	" 12	29.49
Mar. 1	24.70	Sept. 2	30.57
" 15	19.91	" 14	31.53
Apr. 1	20.99	Oct. 3	32.82
" 15	22.07	" 17	33.47
May 3	22.95	Nov. 2	34.42
" 17	23.57	" 16	35.07
June 1	24.49	Dec. 2	35.82
" 15	25.49	" 14	36.22

Date 1912	Feet	Date 1912	Feet
Jan. 2	36.7	June 1	35.3
" 16	36.9	" 15	36.2
Feb. 1	36.0	July 2	37.2
" 15	35.2	" 16	37.75
Mar. 2	35.2	Aug. 1	38.4
" 16	34.15	" 15	39.65
" 26	32.66	Sept. 3	40.1
Apr. 2	32.8	" 17	40.65
" 16	33.1	Oct. 1	41.0
May 2	33.3	" 12	42.2
" 16	34.1		

Future Irrigation Requirements.

Even allowing a contention that the water table will be lowered by the storage on Alameda Creek, irrigation will be confined entirely to the orchard area and to that planted to alfalfa, nursery and strawberries. In the case of the former, the expense of installing pumping machinery and the cost of power and maintenance will act as a deterrent where under normal conditions of rainfall the apricots and cherries will produce as large crops

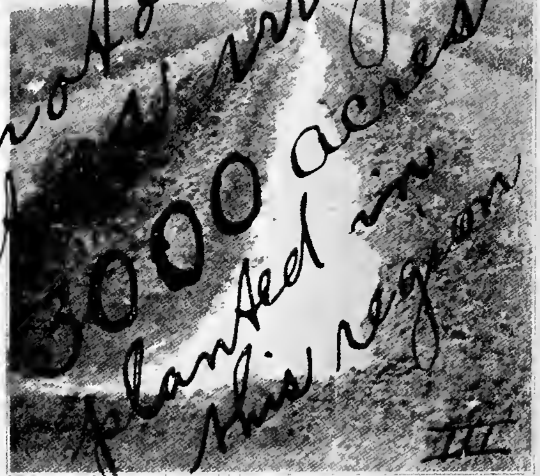


700 GALLONS PER MINUTE PUMPED FROM 8-INCH WELL.

Equivalent to one million gallons in 24 hours, if kept up. Only 25 million gallons pumped during season, which is equivalent to a uniform draft of only 0.068 million gallons per 24 hours.

A WELL ON THE BELL RANCH, DECOTO, CAL.

About four miles northwesterly from apex of Niles Cone. One hundred and eighty-five acres in garden truck.

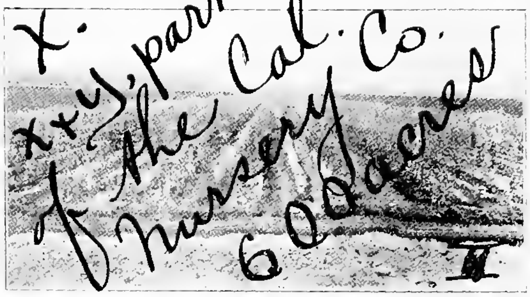


IRRIGATING TOMATOES, BELL RANCH, DECOTO, CAL.

One hundred and eighty-five acres in truck products.

FIFTY-ACRE STRAWBERRY FARM, NILES.

Established in 1911.



IRRIGATING SCENE, CALIFORNIA NURSERY COMPANY, NILES.

Six hundred acres near apex of the underflow, uses over 150 million gallons annually, about one-third of which comes from Spring Valley pipes.

IRRIGATING A FIFTY-ACRE STRAWBERRY FIELD NEAR NILES.

Gross valuue of crop said to be over $50,000 annually.

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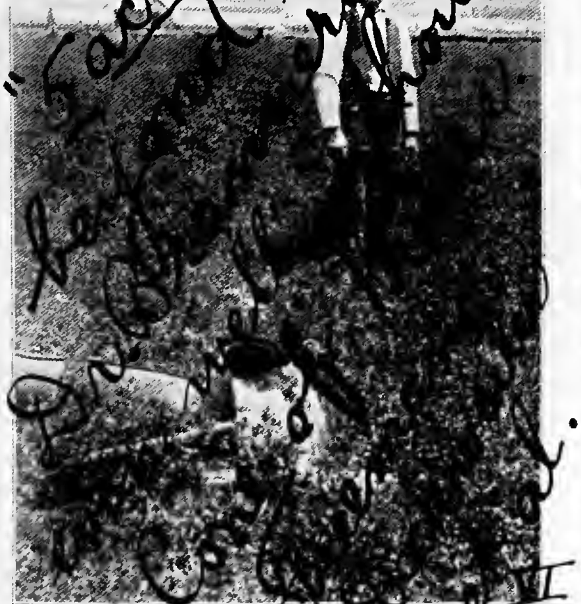
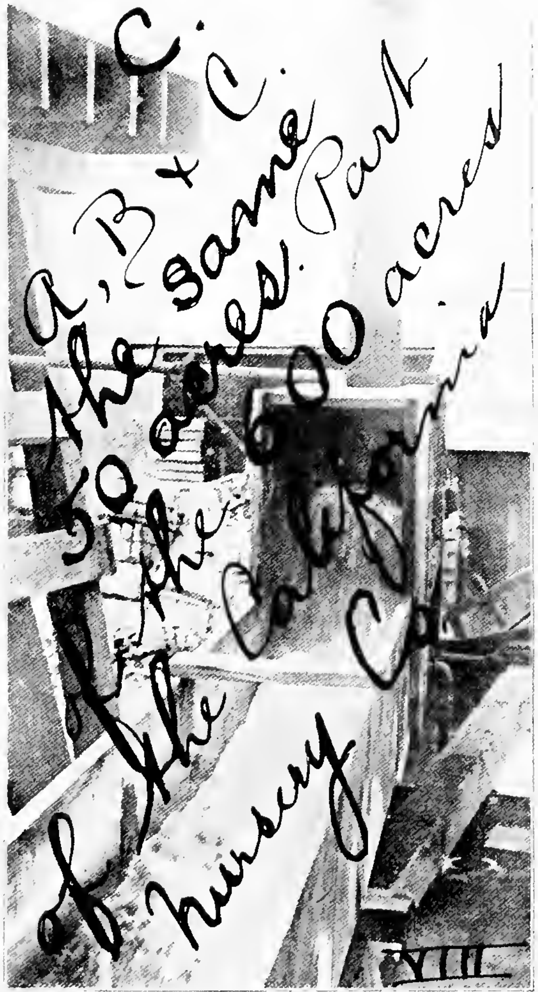
REPRODUCTION OF PAGES 92 AND

Of the 47,360 acres claimed by Freeman as the area of the Niles Cones, only one per cent is under irrigation. On this and the opposite page, three pictures are presented of the same 50-acre strawberry tract, two of young nursery stock of the California Nursery Co., whose lands include the 50-acre strawberry tract referred to. Two pictures are beyond the limits of the cone as fixed by Dr. Branner, and the two remaining are of 20 acres of "truck products."



IRRIGATING ALFALFA, GREGORY RANCH, DECOTO, CAL.

About four miles northwesterly from apex of Niles Cone.



AT THE PUMPING PLANT OF THE NILES STRAWBERRY FARM.

Fifteen-horsepower electric motor; 700 gallons per minute.

THE BART BROWN WELL, ARDEN, NEAR NEWARK, ON THE SOUTHWESTERN MARGIN OF THE NILES CONE.

Pumping ground water from well for the irrigation of an alfalfa field.

IRRIGATING YOUNG APRICOT TREES, CALIFORNIA NURSERY, NEAR NILES.

July 1, 1912.

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93 OF THE FREEMAN REPORT.

These illustrations of irrigation on the Niles Cone represent only one per cent of the area of the alleged cone described by Mr. Freeman.

on unirrigated as on irrigated areas, so that irrigation of orchards will be merely an insurance against dry seasons. The area in orchards is about at a standstill at the present time, for the new plantings will hardly compensate for old orchards whose trees are being removed and the land devoted to summer crops. So it is more than safe to assume that the present area may be taken as the future area.

As regards alfalfa, the district near the tide lands in which the water is always bound to be near the surface and where alfalfa can be grown with the least cost, will be the scene of its greatest development, which will be limited to about double the present area within the described boundaries. One and one-half acre feet per acre have been shown to be sufficient to secure six good crops in this, a *dry year,* and therefore this may be taken safely as the duty of water for this crop. Beginners in irrigation always use more water than is needed, but where they have to pump the water and pay for the cost of operation and maintenance of their pumping plants they soon learn to use it economically and to the best advantage. Furthermore, it is the opinion of the writer that at least a large number of the alfalfa farmers will use water more for the purpose of destroying rodents than for the increase in yield, and that they will learn when the young of the gophers, etc., are in the burrows, so as to confine irrigation to those periods and obtain the best results.

As regards marsh land reclamation, even if it were included within the cone limits, it may be disregarded entirely on account of the excessive cost and the use of water only during the period of reclamation.

Therefore, summing up, we find that of the 8860 acres included within the cone, the present acreage in summer crops, which is much more likely to increase than to decrease, requires no irrigation and will not require any, no matter where the water table is located; the orchards, on account of the early ripening, will need at most two irrigations in years of severe drought, but in ordinary years none, and even in the former case 50 per cent of the orchardists will take chances with the season rather than go to the extra expense. Therefore, it is safe to assume that one-half an acre foot per acre on one-half of the area would be the maximum in any year, or 513 acre feet for this purpose. The area in alfalfa, as placed for the future at 1200 acres, is a liberal allowance, considering the high values, and 1½ acre feet per acre per year is more than enough, as much of this area will not be irrigated more than once or twice, and a portion will receive no water whatsoever on account of the expense when six or seven crops can be grown without going to that expense.

In the nursery area there are large blocks of ornamental trees and variety orchard of such age that they do not require irrigation and will not require any if cultivation is properly maintained. Only the younger trees need water during the growing period; or to be liberal, say 200 acres, allowing three acre feet per acre.

Berries may increase to an area of say 200 acres with water requirements of 6 acre feet per acre; therefore, we have the greatest possible future requirement for irrigation:

Maximum Yearly Requirement of Water for Irrigation in the Niles Cone.

Acres.		Acre Feet.
4,500	Summer crops—no irrigation.	
2,050	Orchard, ½ or 1,025 acres at ½ acre foot per acre..................	513
1,200	Alfalfa at 1½ acre feet per acre...	1,800
200	Grain—no irrigation	
200	Nursery at 3 acre feet per acre....	600
280	" —no irrigation	
200	Strawberries at 6 acre feet per acre	1,200
45	Eucalyptus—no irrigation.	
185	Townsites, pasture, house, lots, etc. —no irrigation	
8,860		4,113

The hill drainage of Alameda Creek below the Sunol Dam amounts to approximately 16,000 acres, with a run-off of about six inches, which is equivalent to 8000 acre feet to store within the limits of the cone, or nearly double the irrigation requirements. Upon complete development of the Spring Valley System, Mr. Herrmann's report of August 1st, 1912, shows that there will be an average waste over the Sunol Dam of 14.6 M. G. daily, or 16,400 acree feet per year. Possibly one-fifth of the irrigation water would be used before June 15th, or during the period in which the cone would be receiving an ample supply from all this drainage. A city representative estimates that the present storage capacity of the Niles Cone above sea level, with the water table as at the time of his report (July, 1912), is approximately 20,000 acre feet. It is

safe to assume that in any normal year this storage will be at this figure on June 15th. After this date 3,300 acre feet might be required for irrigation.

For domestic use, 1,500 acre feet of water would be needed, estimating that the entire area will be subdivided into small farms and that the towns of Niles and Centerville will increase greatly in population, or to a total of say 10,000 people, with a per capita consumption of 150 gallons per day. Therefore, the water requirements of the cone would be:

	Acre Feet.
For domestic use	1,500
" irrigation	4,113
Total	5,613

The run-off from the 16,000 acres drainage below Sunol Dam in a normal year of 20-inch rainfall is 8000 acre feet, while in a rainfall of this amount, and dependent upon the intensity of the storm, there will be a considerable percentage of water falling on the surface of the cone area (8860 acres) which will percolate beyond the reach of plant growth and be added to the storage in the gravels. Placing this amount at only 5 per cent of the rainfall would mean 750 acre feet; therefore it is quite evident that even with the entire flow above the Sunol Dam cut off, which Mr. Herrmann shows to be 16,400 acre feet after all the Spring Valley Water Company's resources have been developed, there would always be more than enough water to supply the requirements of the cone.

In its final solution the future of the Niles Cone must be sought in its agricultural conditions and possibilities and not in hypothetical facts of enginea ng. Under the floor of San Francisco Bay ai d its salt marshes are bodies of fresh artesian water as determined by engineers, but crops cannot be grown on these salt marshes unless reclaimed, nor on the floor of the bay, nor does the discovery of artesian waters place crops on these grounds. Engineers have also located large bodies of water under the Niles Cone, but can any of them prove that the crops on the overlying lands receive moisture required for their growth from a depth of twenty-five to fifty feet. The success of the farmer, the greatest returns per acre, depend upon the fundamental principle of intensive tillage of the soil and not upon any investigations into hydraulics by even the best known of engineers.

F. W. ROEDING.

ADDENDA.

Yearly water supply requirements of the Niles Cone after complete development of the Spring Valley Water Company's resources:

	Acre feet
Waste over the Sunol Dam	16,400
Hill drainage below Sunol Dam	8,000
Percolating rainfall on cone area	750
Total	25,150
Maximum water requirements of the cone	5,613
Surplus	19.537

The surplus over the maximum requirements in round numbers is therefore 6,000 million gallons or 16.5 M. G. D.

Appendix A.

RAINFALL OF THE ALAMEDA SYSTEM

BY

J. J. SHARON,

Assistant Engineer Spring Valley Water Company.

A continual circulation of water is in progress on the surface of the earth. Water evaporates from water surfaces and moist soil surfaces, rises into the atmosphere in the form of vapor, sometimes partially visible as clouds, mist and fog, and is afterwards precipitated as rain.

The distribution of precipitation is by no means uniform. In California there is a great diversity of rainfall sometimes within short distances, and even within the same catchment area.

The great variation in the distribution of the rainfall in the various portions of the Alameda System may be judged from the records showing the average rainfall at three points within that system.

At the Lick Observatory (elevation 4200 feet) for 31 years (1881-82 to 1911-12) it is 31.26 inches; at Calaveras Reservoir (elevation 600 feet) for 34 years [1874-75 to 1911-12 (the records for the years 1886-87, 1887-88, 1908-09 and 1909-10 are missing)] it is 26.40 inches; and at Livermore (elevation 485 feet) for 41 years (1871-72 to 1911-12) it is 15.66 inches.

Topography Influences Rainfall.

In general the rainfall is influenced by topographical features and altitude. On the Pacific Coast and in the Sierras the higher rainfalls occur in the mountainous regions. The mountain ranges intercept the moisture as it comes from the ocean, thus causing heavy rainfalls in those higher altitudes. In fact the intervention of the mountainous regions on the Peninsula and in the Alameda System may be said to be the cause of the much smaller rainfall in the San Francisco Bay, Santa Clara and San Joaquin Valleys. On Plate A I the relation between the rainfall in the mountainous regions on the Peninsula, in the Alameda System, and in the valleys is shown diagrammatically. The mean rainfall and the elevation of the stations are plotted as ordinates, and the distance inland of the station as abscissae.

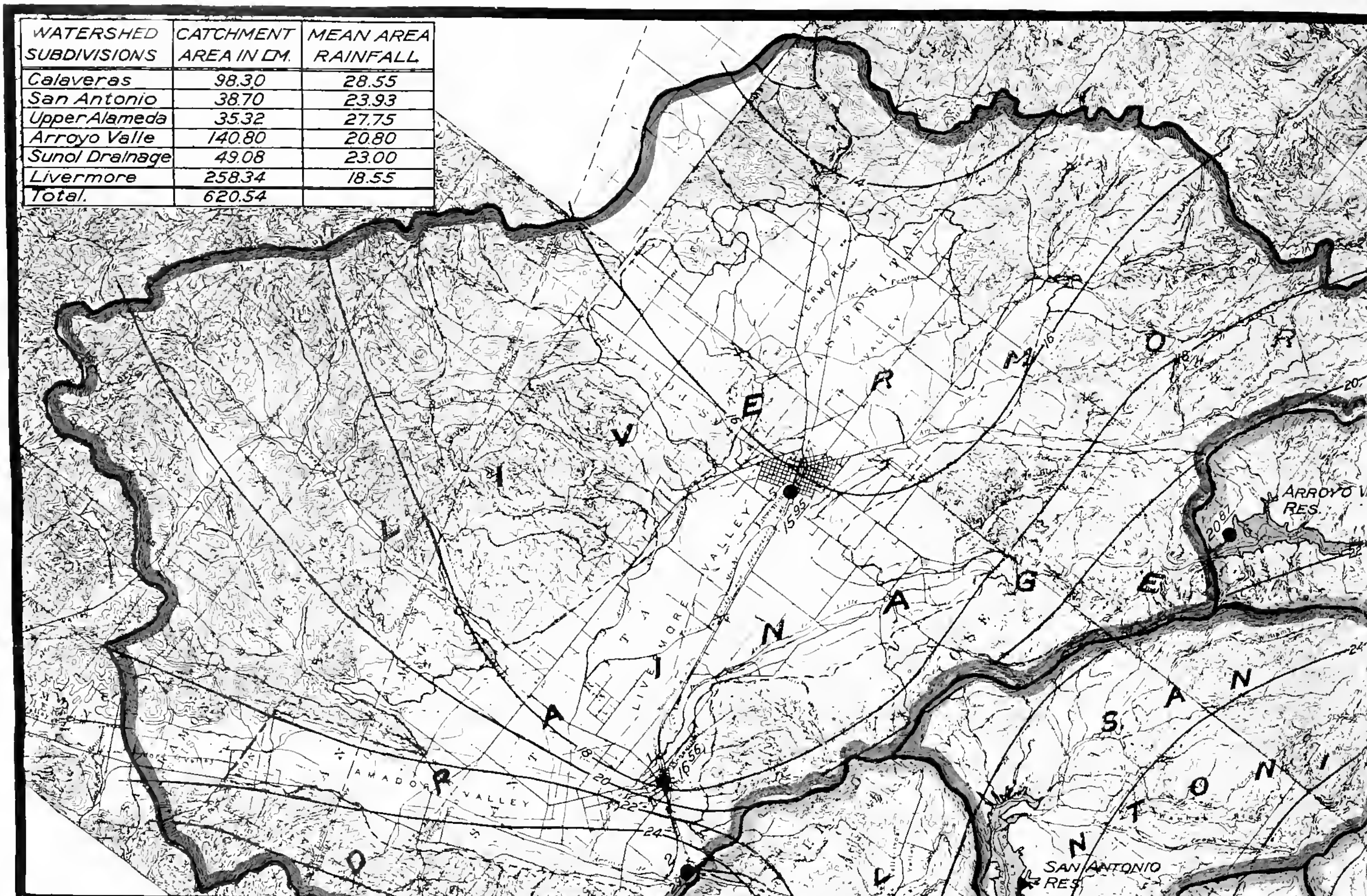
On Plate A 2 there is shown a list of all the rainfall stations whose records were studied, together with the periods of observation, the observed average rainfall and the expanded long term average rainfall for each station. These rainfall stations have been located on the Map (Plate A 2) of the Alameda System.

Value of Long Records.

The quantity of rain falling upon a catchment area, fluctuates yearly, and within the year, and its distribution may be subject to extreme variation from month to month.

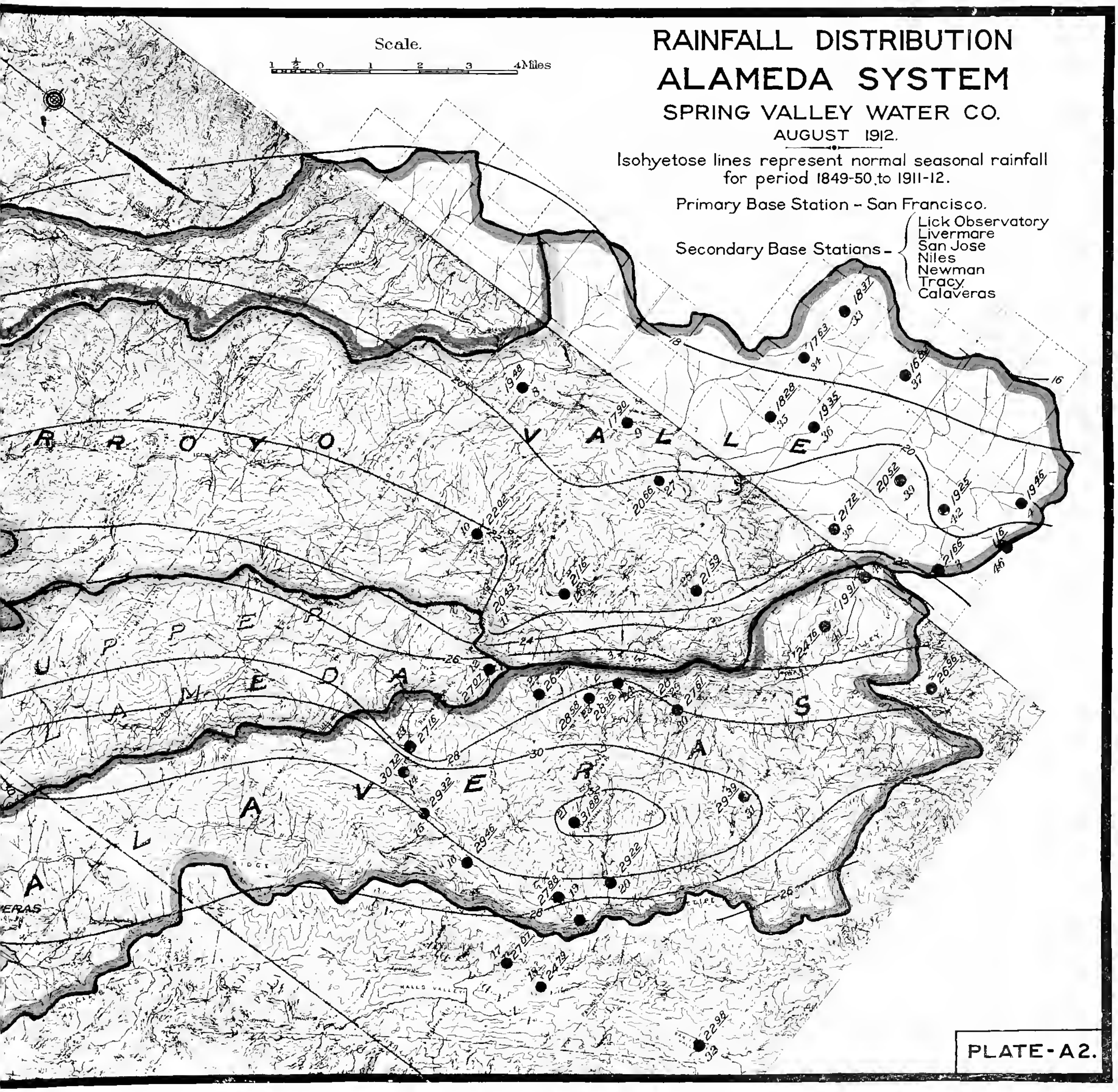
The westerly portion of the Alameda System is well within the relatively humid portion of California, while the easterly portion is not far distant from the relatively arid San Joaquin Valley.

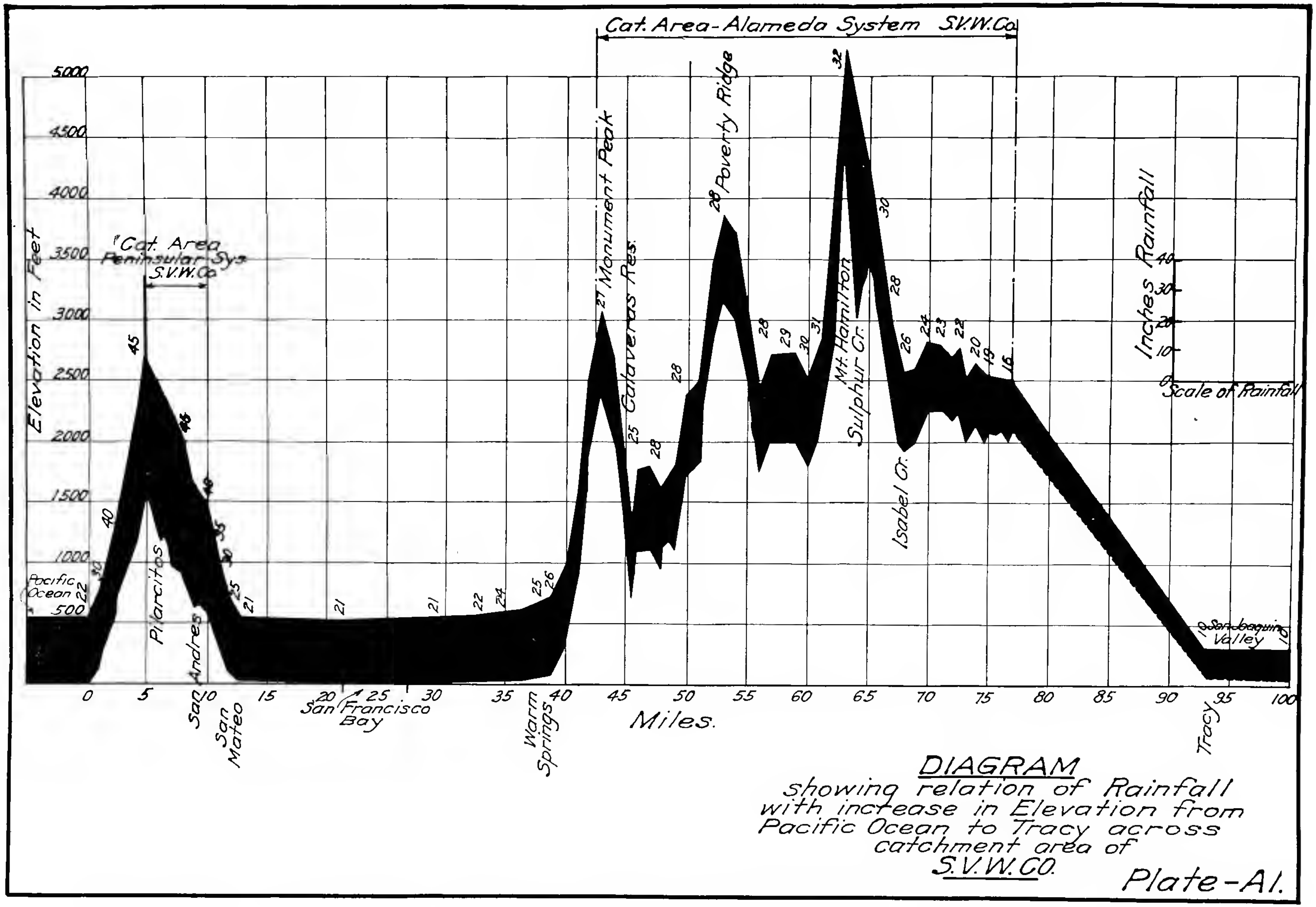
It is noteworthy, however, that most of the storms in the Bay region of California cover extended areas. Local intense rains over restricted areas are unusual, with the result that seasonal rainfall at any one station in this region is a fairly good index of the precipitation elsewhere in the region. Long rainfall records have much greater weight than have those covering shorter perids, and it is customary in engineering practice to expand short records by comparison with the longest available records.



WATERSHED SUBDIVISIONS	CATCHMENT AREA IN □M.	MEAN AREA RAINFALL
Calaveras	98.30	28.55
San Antonio	38.70	23.93
Upper Alameda	35.32	27.75
Arroyo Valle	140.80	20.80
Sunol Drainage	49.08	23.00
Livermore	258.34	18.55
Total.	620.54	

No.	OBSERVED RECORD	OBSVD. MEAN RAIN-FALL	EXPAND. MEAN RAIN-FALL
1	1906-7 to 1911-12	16.38	16.56
2	1899-00 " "	25.21	25.29
3	1886-87 " "	19.87	19.39
4	1889-90 " "	22.07	21.58
5	1871-72 " "	15.66	15.95
6	1904-05 to 1905-6	23.66	20.87
7	1874-75 " 1911-12	26.40	26.73
8	Sep. 03 to Aug. 05	38.73	19.48
9	" " "	35.58	17.90
10	" " Aug. 04	19.59	22.02
11	" Aug. 05	40.70	20.43
12	" " "	53.81	27.07
13	" " "	57.08	27.16
14	" " Aug. 07	139.59	30.72
15	" " "	133.24	29.32
16	" " Aug. 05	58.93	29.46
17	Sep." 05 to " 88	53.84	27.07
18	Sep. 03 " Aug. 05	49.28	24.79
19	" " Aug. 04	24.80	27.88
20	" " Aug. 05	58.08	29.22
21	1881-82 to 1911-12	31.96	31.88
22	Sep. 03 " Aug. 05	52.63	26.48
23	Sep. 03 to Aug. 05	56.81	28.58
24	" " "	56.35	28.36
25	" " "	54.21	27.28
26	" " "	42.06	21.16
27	" " "	41.08	20.66
28	" " "	42.91	21.59
29	" " "	52.74	26.60
30	" " "	54.88	27.61
31	" " Aug. 04	29.00	29.39
32	Jan. 03 " Aug. 05	57.63	22.98
33	Sep. 03 " "	36.51	18.37
34	" " "	35.05	17.63
35	" " "	36.33	18.28
36	" " "	38.46	19.35
37	" " "	33.45	16.82
38	" " "	43.18	21.72
39	" " "	40.79	20.52
40	Sep. 03 to Aug. 05	39.54	19.91
41	" " Aug. 04	24.57	24.76
42	" " Aug. 05	38.29	19.25
43	" " "	43.06	21.66
44	" " Aug. 04	26.75	26.96
45	" " Aug. 05	38.67	19.46
46	" " "	42.05	21.16


RAINFALL DISTRIBUTION
ALAMEDA SYSTEM
SPRING VALLEY WATER CO.
AUGUST 1912.
Isohyetose lines represent normal seasonal rainfall for period 1849-50 to 1911-12.
Primary Base Station - San Francisco.
Secondary Base Stations - Lick Observatory, Livermore, San Jose, Niles, Newman, Tracy, Calaveras
Scale.
4 Miles
ARROYO VALLE
UPPER ALAMEDA
CALAVERAS
PLATE-A2.



DISTRIBUTION OF RAINFALL FROM THE PACIFIC OCEAN TO THE SAN JOAQUIN VALLEY SHOWN GRAPHICALLY.

That the length of time required to make such records safe as a basis for future estimates, is an important point in the consideration of rainfall records, will be seen from the following comparison of short term records at San Francisco to that station's long term record:

If San Francisco's rainfall record, including 1911-12, was	The average rainfall for this period would be	The average rainfall for this period compared with the actual full record at S. F. would be
10 years long	21.09 inches	92.50% of the full record
20 " "	23.18 "	101.80% " "
25 " "	21.16 "	92.80% " "
30 " "	21.72 "	95.26% " "
40 " "	22.17 "	97.23% " "
50 " "	22.37 "	98.12% " "
55 " "	22.78 "	99.91% " "
63 " "	22.80 "	100. % " "

Comparisons of this kind for the short periods at stations where the records are known for a long period will show departures from the long period averages at those stations.

The conclusion reached, therefore, is that the longer the record, whether it be an actual record, or one that is expanded by comparison with a longer record, the more closely will the longer record approximate the true average rainfall. Then, too, it is probable that no departure from the actual normal, either for a single year or for a series of years, will ever exceed that which occurred in the long term record.

Stations Used in Determination of Rainfall of the Alameda Catchment Area.

The records in the vicinity of the Alameda System have been carefully studied in this manner. The stations whose records have thus been studied are situated on the Peninsula of San Francisco, in the Santa Clara Valley on the east side of the Bay of San Francisco, in the Alameda Watershed, and on the west side of the San Joaquin Valley. They were chosen for the purpose of indicating the distribution and amount of rainfall from the ocean eastwardly, in the mountains as well as in the valleys. The station at San Francisco was taken as a primary base because of its value in covering the longest period in these parts, extending over the 63 consecutive seasons, 1849-50 to 1911-12.

Livermore, within the drainage area, and San Jose, outside of, but within the immediate vicinity of the Alameda drainage areas, have the longest records of any of the stations in the vicinity of the Alameda System. These two stations have been combined, and their means for each year from 1874-75 to 1911-12, have been used to expand to a similar term of years (1874-75 to 1911-12) the seasonal records of Calaveras, Lick Observatory, Niles, Newman and Tracy.

The latter five stations, together with Livermore and San Jose, have been selected, because of their geographical locations, to form the secondary base, (San Francisco being the primary base) from which to expand all the stations named and located on Plate A 2 to long term (63 years) normals.

The records of these five stations were expanded to the same term as the San Jose and Livermore records by comparing their means with the mean of the means of Livermore and San Jose for a period corresponding to their term of record.

The records of each of the seven stations were then expanded from 1874-75 to 1849-50 by comparing their mean record with the mean of San Francisco for a corresponding period of time.

The seven station records thus expanded to 63 year normals, were combined and used as the secondary base station from which to expand all the other rainfall records which were studied.

In expanding the records as above outlined, the ratio of the mean of the short term record to the mean, or the mean of the means of the long term record, was assumed to apply to the whole term of years and the short term record was corrected accordingly. In this manner the records were reduced to the same basis.

The following table shows the rainfall record, actual and expanded, for each year since 1849-50, to and including 1911-12 for each station whose record has been studied. Figures enclosed in parenthesis are estimated in accordance with the method outlined above. Figures under each station refer to its number on Plate A 2.

SIXTY-THREE YEAR RAINFALL RECORD EXPANDED BY COMPARISON WITH SAN FRANCISCO.

	San Francisco	Lick Observatory (21)	Livermore (5)	San Jose	Niles (3)	Newman	Tracy	Calaveras (7)
1849-50	33.10	(42.26)	(23.17)	(22.70)	(28.13)	(15.32)	(14.92)	(38.83)
1850-51	7.42	(10.37)	(5.19)	(5.09)	(6.31)	(3.43)	(3.34)	(8.70)
1851-52	18.46	(25.81)	(12.92)	(12.66)	(15.69)	(8.54)	(8.32)	(21.65)
1852-53	35.26	(49.28)	(24.68)	(24.19)	(29.97)	(16.31)	(15.89)	(41.36)
1853-54	23.87	(33.36)	(16.71)	(16.37)	(20.29)	(11.05)	(10.76)	(28.00)
1854-55	23.76	(33.20)	(16.63)	(16.30)	(20.20)	(10.99)	(10.71)	(27.87)
1855-56	21.66	(30.26)	(15.16)	(14.86)	(18.41)	(10.02)	(9.76)	(25.41)
1856-57	19.91	(27.82)	(13.94)	(13.66)	(16.92)	(9.21)	(8.97)	(23.35)
1857-58	21.81	(30.50)	(15.27)	(14.96)	(18.54)	(10.09)	(9.83)	(25.58)
1858-59	22.22	(31.08)	(15.55)	(15.24)	(18.89)	(10.28)	(10.01)	(26.06)
1859-60	22.27	(31.12)	(15.59)	(15.28)	(18.93)	(10.31)	(10.04)	(26.12)
1860-61	19.72	(27.57)	(13.80)	(13.53)	(16.76)	(8.92)	(8.88)	(23.13)
1861-62	49.27	(68.85)	(34.49)	(33.80)	(41.87)	(22.80)	(22.21)	(57.80)
1862-63	13.74	(19.20)	(9.62)	(9.43)	(11.68)	(6.36)	(6.19)	(16.12)
1863-64	10.08	(14.10)	(7.06)	(6.92)	(8.57)	(4.67)	(4.54)	(11.82)
1864-65	24.73	(34.58)	(17.31)	(16.96)	(21.02)	(11.45)	(11.15)	(29.01)
1865-66	22.93	(32.05)	(16.05)	(15.73)	(19.49)	(10.62)	(10.34)	(26.90)
1866-67	34.92	(48.81)	(24.44)	(23.95)	(29.68)	(16.16)	(15.74)	(40.96)
1867-68	38.84	(54.26)	(27.19)	(26.64)	(33.01)	(17.97)	(17.51)	(45.56)
1868-69	21.35	(29.82)	(14.95)	(14.65)	(18.15)	(9.88)	(9.62)	(25.04)
1869-70	19.31	(27.00)	(13.52)	(13.25)	(16.41)	(8.94)	(8.70)	(22.65)
1870-71	14.11	(19.71)	(9.88)	(9.68)	(11.99)	(6.54)	(6.36)	(16.55)
1871-72	30.78	(43.00)	19.06	(21.11)	(26.16)	(14.24)	(13.87)	(35.50)
1872-73	15.66	(21.89)	10.69	(10.74)	(13.31)	(7.25)	(7.06)	(18.37)
1873-74	24.73	(34.57)	12.26	(16.96)	(21.02)	(11.45)	(11.15)	(29.01)
1874-75	20.56	(18.72)	11.67	7.90	(11.84)	(6.50)	(6.32)	16.28
1875-76	31.19	(39.60)	19.99	19.47	(24.07)	(13.11)	(12.75)	40.50
1876-77	11.04	(10.23)	6.01	4.83	(6.61)	(3.60)	(3.50)	12.15
1877-78	35.18	(38.36)	17.66	19.28	(22.54)	(12.28)	(11.93)	29.02
1878-79	24.44	(30.63)	10.11	16.40	(16.16)	(8.81)	(8.56)	21.43
1879-80	26.66	(28.73)	15.98	13.77	(18.14)	(9.88)	9.20	27.69
1880-81	29.86	(26.79)	16.45	12.45	(17.63)	(9.60)	10.68	25.03
1881-82	16.14	29.15	11.70	11.75	(14.30)	(7.79)	7.27	22.32
1882-83	20.12	37.26	13.86	10.59	(14.92)	(8.13)	8.10	21.40
1883-84	32.38	58.09	22.75	20.08	(26.12)	(14.23)	12.85	37.26
1884-85	18.10	44.67	12.04	11.27	(14.20)	(7.74)	4.91	19.63
1885-86	33.05	31.42	16.17	20.63	(22.45)	(12.23)	12.30	31.66
1886-87	19.04	24.08	11.17	11.36	14.85	(7.48)	7.27	(18.94)
1887-88	16.74	30.03	13.13	12.17	14.94	(8.41)	6.65	(21.28)
1888-89	23.86	21.85	15.81	15.71	15.97	(10.48)	10.31	19.87
1889-90	45.85	45.16	28.66	30.30	35.91	23.67	21.92	45.54
1890-91	17.58	24.05	14.16	12.88	14.83	9.68	9.34	20.23
1891-92	18.53	27.49	14.25	16.51	16.39	9.08	8.98	25.24
1892-93	21.75	37.93	26.29	25.17	23.46	16.28	11.63	39.20
1893-94	18.47	35.84	17.16	12.92	21.91	4.88	9.17	30.81
1894-95	25.70	36.61	24.37	23.32	27.30	14.11	12.11	38.63
1895-96	21.25	29.76	16.35	13.69	19.58	10.23	8.86	25.82
1896-97	23.43	32.22	17.28	16.56	24.02	11.27	9.39	31.20
1897-98	9.38	17.66	9.11	6.87	11.99	5.67	7.20	13.37
1898-99	16.87	25.73	9.27	10.02	15.89	6.27	9.11	20.98
1899-00	18.47	29.31	12.72	13.87	18.55	11.58	14.42	25.84
1900-01	21.17	31.64	19.72	19.88	24.16	12.08	14.10	30.66
1901-02	18.98	27.62	16.80	12.98	18.17	8.27	7.72	23.27
1902-03	18.28	30.29	14.25	13.89	17.16	9.26	10.28	24.95
1903-04	20.59	33.78	13.33	10.47	14.52	7.04	8.68	27.49
1904-05	23.45	28.55	15.81	17.96	23.47	14.85	15.15	28.72
1905-06	20.42	38.43	19.32	15.12	23.89	14.73	11.77	28.04
1906-07	26.17	43.34	23.14	22.71	28.33	15.99	15.73	32.98
1907-08	17.35	23.92	9.93	11.69	12.90	7.68	7.00	17.34
1908-09	25.57	37.42	18.58	18.31	22.64	11.50	12.26	(31.02)
1909-10	19.52	26.02	14.50	14.52	18.33	9.83	8.56	(24.41)
1910-11	25.49	33.29	21.28	22.65	20.58	11.36	10.07	28.12
1911-12	14.00	18.24	9.50	10.58	11.52	6.72	5.55	14.79
Mean	22.80	31.88	15.95	15.63	19.39	10.56	10.29	26.73

SIXTY-THREE YEAR RAINFALL RECORD EXPANDED BY COMPARISON WITH SAN FRANCISCO.

	Calaveras (23)	Calaveras (19)	Calaveras (20)	Calaveras (22)	Calaveras (24)	Calaveras (41)	Calaveras (40)	Calaveras (29)
1849-50	(41.45)	(40.43)	(42.37)	(38.41)	(41.13)	(35.85)	(27.42)	(38.48)
1850-51	(9.29)	(9.06)	(9.50)	(8.61)	(9.22)	(8.04)	(6.15)	(8.62)
1851-52	(23.12)	(22.54)	(23.63)	(21.42)	(22.94)	(20.00)	(15.29)	(21.46)
1852-53	(44.17)	(43.07)	(45.15)	(40.93)	(43.82)	(38.20)	(29.21)	(41.00)
1853-54	(29.89)	(29.15)	(30.56)	(27.70)	(29.66)	(25.86)	(19.77)	(27.75)
1854-55	(29.76)	(29.02)	(30.42)	(27.57)	(29.52)	(25.74)	(19.68)	(27.62)
1855-56	(27.13)	(26.46)	(27.74)	(25.14)	(26.92)	(23.47)	(17.95)	(25.19)
1856-57	(24.94)	(24.32)	(25.50)	(23.11)	(24.75)	(21.57)	(16.50)	(23.15)
1857-58	(27.32)	(26.64)	(27.92)	(25.31)	(27.10)	(23.63)	(18.07)	(25.36)
1858-59	(27.84)	(27.15)	(28.46)	(25.80)	(27.62)	(24.08)	(18.41)	(25.84)
1859-60	(27.90)	(27.21)	(28.52)	(25.86)	(27.68)	(24.13)	(18.45)	(25.90)
1860-61	(24.65)	(24.04)	(25.20)	(22.84)	(24.46)	(21.24)	(16.31)	(22.88)
1861-62	(61.72)	(60.19)	(63.09)	(57.20)	(61.22)	(53.39)	(40.82)	(57.29)
1862-63	(17.22)	(16.79)	(17.60)	(15.95)	(17.08)	(14.89)	(11.39)	(15.98)
1863-64	(12.63)	(12.32)	(12.91)	(11.71)	(12.53)	(10.93)	(8.35)	(11.73)
1864-65	(30.98)	(30.21)	(31.67)	(28.71)	(30.74)	(26.80)	(20.49)	(28.76)
1865-66	(28.73)	(28.02)	(29.37)	(26.62)	(28.50)	(24.85)	(19.00)	(26.67)
1866-67	(43.74)	(42.65)	(44.71)	(40.53)	(43.40)	(37.83)	(28.93)	(40.60)
1867-68	(48.66)	(47.45)	(49.74)	(45.09)	(48.28)	(42.09)	(32.18)	(45.17)
1868-69	(26.74)	(26.07)	(27.33)	(24.78)	(26.53)	(23.13)	(17.69)	(24.82)
1869-70	(24.19)	(23.59)	(24.73)	(22.42)	(24.00)	(20.92)	(16.00)	(22.45)
1870-71	(17.68)	(17.24)	(18.07)	(16.38)	(17.54)	(15.29)	(11.69)	(16.41)
1871-72	(37.87)	(36.93)	(38.71)	(35.09)	(37.57)	(32.75)	(25.05)	(35.15)
1872-73	(20.71)	(20.20)	(21.17)	(19.19)	(20.55)	(17.91)	(13.71)	(19.23)
1873-74	(29.88)	(29.14)	(30.54)	(27.69)	(29.64)	(25.84)	(19.76)	(27.73)
1874-75	(17.35)	(16.92)	(17.74)	(16.08)	(17.22)	(15.01)	(11.48)	(16.11)
1875-76	(37.12)	(36.19)	(37.94)	(34.41)	(36.82)	(32.10)	(24.55)	(34.45)
1876-77	(10.27)	(10.02)	(10.50)	(9.52)	(10.19)	(8.88)	(6.79)	(9.53)
1877-78	(33.08)	(32.26)	(33.82)	(30.66)	(32.82)	(28.62)	(21.88)	(30.71)
1878-79	(24.54)	(23.94)	(25.09)	(22.74)	(24.35)	(21.23)	(16.23)	(22.78)
1879-80	(27.00)	(26.33)	(27.60)	(25.02)	(26.78)	(23.35)	(17.86)	(25.06)
1880-81	(25.98)	(25.34)	(26.56)	(24.08)	(25.78)	(22.47)	(17.19)	(24.12)
1881-82	(22.84)	(22.28)	(23.35)	(21.17)	(22.66)	(19.76)	(15.11)	(21.20)
1882-83	(25.02)	(24.40)	(25.57)	(23.18)	(24.82)	(21.64)	(16.55)	(23.22)
1883-84	(41.91)	(40.88)	(42.84)	(38.84)	(41.58)	(36.25)	(27.72)	(38.91)
1884-85	(25.06)	(24.44)	(25.62)	(23.23)	(24.87)	(21.68)	(16.58)	(23.27)
1885-86	(32.16)	(31.37)	(32.88)	(29.80)	(31.91)	(27.82)	(21.27)	(29.85)
1886-87	(20.83)	(20.32)	(21.30)	(19.31)	(20.67)	(18.02)	(13.78)	(19.34)
1887-88	(23.35)	(22.77)	(23.87)	(21.64)	(23.16)	(20.19)	(15.44)	(21.67)
1888-89	(24.08)	(23.49)	(24.62)	(22.32)	(23.89)	(20.83)	(15.93)	(22.36)
1889-90	(50.62)	(49.37)	(51.74)	(46.91)	(50.22)	(43.78)	(33.48)	(46.99)
1890-91	(23.03)	(22.45)	(23.54)	(21.34)	(22.84)	(19.92)	(15.23)	(21.37)
1891-92	(25.83)	(25.19)	(26.40)	(23.94)	(25.63)	(22.34)	(17.09)	(23.98)
1892-93	(39.41)	(38.44)	(40.29)	(36.53)	(39.10)	(34.09)	(26.07)	(36.59)
1893-94	(29.07)	(28.34)	(29.71)	(26.93)	(28.84)	(25.14)	(19.23)	(26.98)
1894-95	(38.65)	(37.69)	(39.50)	(35.81)	(38.34)	(33.43)	(25.56)	(40.14)
1895-96	(27.21)	(26.54)	(27.81)	(25.22)	(27.00)	(23.54)	(18.00)	(25.26)
1896-97	(31.09)	(30.32)	(31.78)	(28.81)	(30.85)	(26.89)	(20.56)	(28.86)
1897-98	(15.74)	(15.35)	(16.09)	(14.59)	(15.62)	(13.62)	(10.41)	(14.61)
1898-99	(21.29)	(20.77)	(21.77)	(19.73)	(21.13)	(18.42)	(14.08)	(19.77)
1899-00	(27.65)	(26.97)	(28.27)	(25.63)	(27.44)	(23.92)	(18.29)	(25.67)
1900-01	(33.34)	(32.52)	(34.08)	(30.90)	(33.08)	(28.84)	(22.06)	(30.95)
1901-02	(25.16)	(24.53)	(25.72)	(23.31)	(24.96)	(21.76)	(16.64)	(23.35)
1902-03	(26.29)	(25.64)	(26.88)	(24.36)	(26.08)	(22.74)	(17.39)	(24.40)
1903-04	.....	24.80	.....	.....	.....	24.57	.....	.....
	56.81	.....	58.08	52.63	56.35	.....	39.54	52.74
1904-05	.....	(30.86)	.....	.....	.....	(27.37)	.....	.....
1905-06	(33.13)	(32.31)	(33.86)	(30.70)	(32.87)	(28.65)	(21.91)	(30.75)
1906-07	(39.90)	(38.92)	(40.79)	(36.98)	(39.59)	(34.52)	(26.39)	(37.04)
1907-08	(19.81)	(19.32)	(20.25)	(18.35)	(19.65)	(17.13)	(13.10)	(18.39)
1908-09	(33.23)	(32.41)	(33.97)	(30.80)	(32.97)	(28.75)	(21.98)	(30.85)
1909-10	(25.45)	(24.82)	(26.01)	(23.58)	(25.25)	(22.01)	(16.83)	(23.62)
1910-11	(32.27)	(31.47)	(32.99)	(29.90)	(32.02)	(27.91)	(21.34)	(29.95)
1911-12	(16.83)	(16.41)	(17.21)	(15.60)	(16.70)	(14.56)	(11.13)	(15.63)
Mean	28.58	27.88	29.22	26.48	28.36	24.76	19.91	26.60

SIXTY-THREE YEAR RAINFALL RECORD EXPANDED BY COMPARISON WITH SAN FRANCISCO.

	Calaveras (16)	Calaveras (13)	Calaveras (30)	Calaveras (14)	Calaveras (15)	Calaveras (31)
1849-50	(42.72)	(39.32)	(40.05)	(44.56)	(42.53)	(42.32)
1850-51	(9.58)	(8.81)	(8.97)	(9.99)	(9.53)	(9.48)
1851-52	(23.83)	(21.93)	(22.33)	(24.85)	(23.72)	(23.60)
1852-53	(45.52)	(41.89)	(42.67)	(47.48)	(45.32)	(45.09)
1853-54	(30.81)	(28.35)	(28.88)	(32.13)	(30.68)	(30.52)
1854-55	(30.67)	(28.22)	(28.75)	(31.99)	(30.53)	(30.38)
1855-56	(27.97)	(25.74)	(26.21)	(29.17)	(27.84)	(27.70)
1856-57	(25.71)	(23.66)	(24.10)	(26.81)	(25.59)	(25.46)
1857-58	(28.16)	(25.91)	(26.39)	(29.37)	(28.03)	(27.89)
1858-59	(28.69)	(26.40)	(26.89)	(29.93)	(28.56)	(28.42)
1859-60	(28.76)	(26.46)	(26.95)	(29.99)	(28.63)	(28.48)
1860-61	(25.41)	(23.38)	(23.81)	(26.50)	(25.29)	(25.17)
1861-62	(63.60)	(58.54)	(59.62)	(66.34)	(63.33)	(63.00)
1862-63	(17.74)	(16.33)	(16.63)	(18.51)	(17.66)	(17.58)
1863-64	(13.02)	(11.98)	(12.20)	(13.58)	(12.96)	(12.90)
1864-65	(31.93)	(29.38)	(29.93)	(33.30)	(31.79)	(31.63)
1865-66	(29.61)	(27.25)	(27.76)	(30.88)	(29.48)	(29.33)
1866-67	(45.08)	(41.48)	(42.25)	(47.02)	(44.88)	(44.65)
1867-68	(50.15)	(46.15)	(47.01)	(52.30)	(49.93)	(49.68)
1868-69	(27.56)	(25.36)	(25.83)	(28.74)	(27.44)	(27.30)
1869-70	(24.93)	(22.94)	(23.37)	(26.01)	(24.82)	(24.70)
1870-71	(18.22)	(16.77)	(17.08)	(19.00)	(18.14)	(18.04)
1871-72	(39.03)	(35.91)	(36.58)	(40.70)	(38.85)	(38.66)
1872-73	(21.35)	(19.64)	(20.01)	(22.26)	(21.25)	(21.14)
1873-74	(30.80)	(28.34)	(28.86)	(32.12)	(30.66)	(30.50)
1874-75	(17.89)	(16.46)	(16.76)	(18.66)	(17.81)	(17.72)
1875-76	(38.25)	(35.20)	(35.85)	(39.90)	(38.08)	(37.89)
1876-77	(10.59)	(9.74)	(9.92)	(11.04)	(10.54)	(10.49)
1877-78	(34.10)	(31.38)	(31.96)	(35.56)	(33.95)	(33.77)
1878-79	(25.30)	(23.28)	(23.71)	(26.38)	(25.18)	(25.06)
1879-80	(27.83)	(25.61)	(26.08)	(29.02)	(27.70)	(27.56)
1880-81	(26.78)	(24.65)	(25.10)	(27.93)	(26.66)	(36.53)
1881-82	(23.54)	(21.66)	(22.07)	(24.56)	(23.44)	(23.32)
1882-83	(25.79)	(23.73)	(24.17)	(26.90)	(25.67)	(25.54)
1883-84	(43.20)	(39.75)	(40.49)	(45.06)	(43.01)	(42.79)
1884-85	(25.83)	(23.77)	(24.21)	(26.94)	(25.72)	(25.59)
1885-86	(33.15)	(30.51)	(31.07)	(34.57)	(33.00)	(32.84)
1886-87	(21.47)	(19.76)	(20.13)	(22.40)	(21.38)	(21.27)
1887-88	(24.06)	(22.14)	(22.55)	(25.10)	(23.96)	(23.84)
1888-89	(24.82)	(22.84)	(23.27)	(25.89)	(24.71)	(24.59)
1889-90	(52.17)	(48.01)	(48.90)	(54.42)	(51.94)	(51.68)
1890-91	(23.73)	(21.84)	(22.24)	(24.75)	(23.63)	(23.51)
1891-92	(26.62)	(24.50)	(24.95)	(27.77)	(26.51)	(26.37)
1892-93	(40.62)	(37.38)	(38.08)	(42.37)	(40.44)	(40.24)
1893-94	(29.96)	(27.57)	(28.08)	(31.25)	(29.82)	(29.67)
1894-95	(39.83)	(36.66)	(37.33)	(41.55)	(39.65)	(39.45)
1895-96	(28.04)	(25.81)	(26.29)	(29.25)	(27.92)	(27.78)
1896-97	(32.04)	(29.49)	(30.03)	(33.42)	(31.90)	(31.74)
1897-98	(16.23)	(14.93)	(15.21)	(16.92)	(16.15)	(16.07)
1898-99	(21.95)	(20.20)	(20.58)	(22.89)	(21.85)	(21.74)
1899-00	(28.50)	(26.23)	(26.72)	(29.73)	(28.38)	(28.23)
1900-01	(34.37)	(31.62)	(32.21)	(35.84)	(34.21)	(34.04)
1901-02	(25.93)	(23.86)	(24.30)	(27.04)	(25.81)	(25.68)
1902-03	(27.10)	(24.94)	(25.40)	(28.26)	(26.98)	(26.84)
1903-04 } 1904-05	58.93	57.08	54.88	139.59	133.24	29.00 (32.30)
1905-06	(34.14)	(31.42)	(32.00)	(For 4 years)		(33.82)
1906-07	(41.13)	(37.85)	(38.55)	....	....	(40.74)
1907-08	(20.41)	(18.79)	(19.14)	(21.29)	(20.32)	(20.22)
1908-09	(34.25)	(31.52)	(32.11)	(35.73)	(34.10)	(33.93)
1909-10	(26.23)	(24.14)	(24.58)	(27.36)	(26.11)	(25.98)
1910-11	(33.26)	(30.61)	(31.17)	(34.69)	(33.11)	(32.94)
1911-12	(17.35)	(15.97)	(16.26)	(18.10)	(17.27)	(17.18)
Mean	29.46	27.16	27.61	30.72	29.32	29.39

SIXTY-THREE YEAR RAINFALL RECORD EXPANDED BY COMPARISON WITH SAN FRANCISCO.

	Arroyo Valle (25)	Arroyo Valle (42)	Arroyo Valle (10)	Arroyo Valle (11)	Arroyo Valle (39)	Arroyo Valle (43)	Arroyo Valle (28)	Arroyo Valle (38)
1849-50........	(39.56)	(27.93)	(31.93)	(29.63)	(29.77)	(31.42)	(31.31)	(31.50)
1850-51........	(8.87)	(6.26)	(7.16)	(6.64)	(6.67)	(7.04)	(7.02)	(7.06)
1851-52........	(22.06)	(15.58)	(17.81)	(16.53)	(16.60)	(17.52)	(17.46)	(17.57)
1852-53........	(42.15)	(29.76)	(34.02)	(31.57)	(31.72)	(33.48)	(33.36)	(33.56)
1853-54........	(28.53)	(20.14)	(23.03)	(21.37)	(21.47)	(22.66)	(22.58)	(22.72)
1854-55........	(28.40)	(20.05)	(22.92)	(21.27)	(21.37)	(22.55)	(22.48)	(22.61)
1855-56........	(25.90)	(18.28)	(20.90)	(19.40)	(19.49)	(20.57)	(20.50)	(20.62)
1856-57........	(23.80)	(16.81)	(19.22)	(17.83)	(17.91)	(18.91)	(18.84)	(18.95)
1857-58.... ..	(26.07)	(18.41)	(21.04)	(19.53)	(19.62)	(20.71)	(20.64)	(20.76)
1858-59........	(26.57)	(18.76)	(21.45)	(19.90)	(19.99)	(21.10)	(21.03)	(21.16)
1859-60........	(26.63)	(18.80)	(21.49)	(19.95)	(20.04)	(21.15)	(21.07)	(21.20)
1860-61........	(23.53)	(16.61)	(18.99)	(17.62)	(17.70)	(18.69)	(18.62)	(18.73)
1861-62........	(58.90)	(41.59)	(47.55)	(44.12)	(44.32)	(46.79)	(46.62)	(46.90)
1862-63........	(16.43)	(11.60)	(13.26)	(12.31)	(12.36)	(13.05)	(13.00)	(13.08)
1863-64........	(12.06)	(8.51)	(9.73)	(9.03)	(9.07)	(9.58)	(9.54)	(9.60)
1864-65........	(29.57)	(20.88)	(23.87)	(22.15)	(22.25)	(23.48)	(23.40)	(23.53)
1865-66........	(27.42)	(19.36)	(22.13)	(20.54)	(20.63)	(21.78)	(21.70)	(21.83)
1866-67........	(41.74)	(29.47)	(33.69)	(31.27)	(31.41)	(33.15)	(33.04)	(33.24)
1867-68........	(46.44)	(32.79)	(37.48)	(34.79)	(34.94)	(36.88)	(36.75)	(36.98)
1868-69........	(25.52)	(18.02)	(20.60)	(19.11)	(19.20)	(20.27)	(20.20)	(20.32)
1869-70........	(23.09)	(16.30)	(18.64)	(17.29)	(17.37)	(18.34)	(18.27)	(18.38)
1870-71........	(16.87)	(11.91)	(13.62)	(12.64)	(12.69)	(13.40)	(13.35)	(13.43)
1871-72........	(36.14)	(25.51)	(29.17)	(27.07)	(27.19)	(28.70)	(28.60)	(28.78)
1872-73........	(19.77)	(13.96)	(15.96)	(14.81)	(14.87)	(15.70)	(15.64)	(15.74)
1873-74........	(28.51)	(20.13)	(23.02)	(21.36)	(21.46)	(22.65)	(22.57)	(22.71)
1874-75........	(16.56)	(11.69)	(13.37)	(12.41)	(12.46)	(13.15)	(13.11)	(13.19)
1875-76........	(35.42)	(25.01)	(28.59)	(26.53)	(26.65)	(28.13)	(28.04)	(28.21)
1876-77........	(9.80)	(6.92)	(7.91)	(7.34)	(7.38)	(7.79)	(7.76)	(7.81)
1877-78........	(31.57)	(22.29)	(25.48)	(23.65)	(23.76)	(25.08)	(24.99)	(25.14)
1878-79........	(23.42)	(16.54)	(18.91)	(17.55)	(17.63)	(18.60)	(18.54)	(18.65)
1879-80........	(25.76)	(18.19)	(20.80)	(19.30)	(19.39)	(20.46)	(20.39)	(20.52)
1880-81........	(24.80)	(17.51)	(20.02)	(18.58)	(18.66)	(19.70)	(19.63)	(19.75)
1881-82........	(21.80)	(15.39)	(17.60)	(16.33)	(16.41)	(17.32)	(17.25)	(17.36)
1882-83........	(23.88)	(16.86)	(19.27)	(17.89)	(17.97)	(18.96)	(18.90)	(19.01)
1883-84........	(40.00)	(28.24)	(32.29)	(29.96)	(30.10)	(31.77)	(31.65)	(31.85)
1884-85........	(23.92)	(16.89)	(19.31)	(17.92)	(18.00)	(19.00)	(18.93)	(19.05)
1885-86	(30.70)	(21.67)	(24.78)	(22.99)	(23.10)	(24.38)	(24.29)	(24.44)
1886-87........	(19.88)	(14.04)	(16.05)	(14.89)	(14.96)	(15.79)	(15.74)	(15.83)
1887-88	(22.28)	(15.73)	(17.99)	(16.69)	(16.77)	(17.70)	(17.64)	(17.74)
1888-89........	(22.98)	(16.23)	(18.55)	(17.22)	(17.30)	(18.26)	(18.19)	(18.30)
1889-90........	(48.31)	(34.10)	(39.00)	(36.19)	(36.35)	(38.37)	(38.24)	(38.47)
1890-91........	(21.97)	(15.52)	(17.74)	(16.46)	(16.54)	(17.45)	(17.39)	(17.50)
1891-92........	(24.65)	(17.41)	(19.90)	(18.47)	(18.55)	(19.58)	(19.51)	(19.63)
1892-93........	(37.61)	(26.56)	(30.36)	(28.18)	(28.31)	(29.88)	(29.77)	(29.95)
1893-94........	(27.74)	(19.59)	(22.39)	(20.78)	(20.87)	(22.03)	(21.96)	(22.09)
1894-95........	(36.88)	(26.04)	(29.77)	(27.63)	(27.75)	(29.29)	(29.19)	(29.37)
1895-96........	(25.97)	(18.34)	(20.96)	(19.45)	(19.54)	(20.63)	(20.55)	(20.68)
1896-97........	(29.67)	(20.95)	(23.95)	(22.23)	(22.33)	(23.57)	(23.48)	(23.63)
1897-98........	(15.02)	(10.61)	(12.13)	(11.26)	(11.31)	(11.93)	(11.89)	(11.96)
1898-99........	(20.32)	(14.35)	(16.40)	(15.22)	(15.29)	(16.14)	(16.08)	(16.18)
1899-00........	(26.39)	(18.64)	(21.30)	(19.77)	(19.86)	(20.96)	(20.89)	(21.08)
1900-01........	(31.82)	(22.47)	(25.69)	(23.84)	(23.95)	(25.27)	(25.19)	(25.34)
1901-02........	(24.01)	(16.95)	(19.38)	(17.98)	(18.07)	(19.07)	(19.00)	(19.12)
1902-03........	(25.09)	(17.72)	(20.25)	(18.80)	(18.88)	(19.63)	(19.86)	(19.98)
1904-05........	54.21	38.29	(24.38)*	40.70	40.79	43.06	42.91	43.18
1905-06........	(31.62)	(22.32)	(25.52)	(23.68)	(23.79)	(25.11)	(25.02)	(25.18)
1906-07........	(38.08)	(26.89)	(30.74)	(28.53)	(28.66)	(30.25)	(30.14)	(30.33)
1907-08........	(18.90)	(13.35)	(15.26)	(14.16)	(14.22)	(15.01)	(14.96)	(15.05)
1908-09	(31.72)	(22.40)	(25.60)	(23.76)	(23.87)	(25.19)	(25.10)	(25.26)
1909-10........	(24.29)	(17.15)	(19.60)	(18.19)	(18.28)	(19.29)	(19.22)	(19.34)
1910-11........	(30.80)	(21.74)	(24.86)	(23.07)	(23.18)	(24.46)	(24.38)	(24.52)
1911-12........	(16.06)	(11.34)	(12.97)	(12.03)	(12.09)	(12.76)	(12.71)	(12.79)
*1903-04......	.....	.....	19.59	.....	.....	.....	.....	.....
Mean	27.28	19.25	22.02	20.43	20.52	21.66	21.59	21.72

SIXTY-THREE YEAR RAINFALL RECORD EXPANDED BY COMPARISON WITH SAN FRANCISCO.

	Arroyo Valle (33)	Arroyo Valle (45)	Arroyo Valle (36)	Arroyo Valle (8)	Arroyo Valle (9)	Arroyo Valle (35)	Arroyo Valle (27)	Arroyo Valle (26&46)
1849-50.........	(26.65)	(28.23)	(28.07)	(28.26)	(25.96)	(26.52)	(29.96)	(30.69)
1850-51.........	(5.97)	(6.33)	(6.29)	(6.33)	(5.82)	(5.94)	(6.71)	(6.88)
1851-52.........	(14.85)	(15.74)	(15.65)	(15.76)	(14.48)	(14.79)	(16.71)	(17.12)
1852-53.........	(28.39)	(30.08)	(29.90)	(30.11)	(27.66)	(28.25)	(31.92)	(32.70)
1853-54.........	(19.22)	(20.36)	(20.24)	(20.38)	(18.72)	(19.12)	(21.61)	(22.13)
1854-55.........	(19.13)	(20.26)	(20.15)	(20.28)	(18.63)	(19.03)	(21.51)	(22.03)
1855-56.........	(17.44)	(18.48)	(18.37)	(18.50)	(16.99)	(17.36)	(19.61)	(20.09)
1856-57.........	(16.03)	(16.99)	(16.89)	(17.00)	(15.62)	(15.95)	(18.03)	(18.47)
1857-58.........	(17.56)	(18.60)	(18.50)	(18.62)	(17.11)	(17.48)	(19.75)	(20.23)
1858-59.........	(17.89)	(18.96)	(18.85)	(18.98)	(17.43)	(17.81)	(20.12)	(20.61)
1859-60.........	(17.93)	(19.00)	(18.89)	(19.02)	(17.47)	(17.85)	(20.16)	(20.66)
1860-61.........	(15.85)	(16.79)	(16.69)	(16.80)	(15.44)	(15.77)	(17.82)	(18.25)
1861-62.........	(39.67)	(42.03)	(41.79)	(42.07)	(38.65)	(39.47)	(44.61)	(45.70)
1862-63.........	(11.07)	(11.72)	(11.66)	(11.74)	(10.78)	(11.01)	(12.44)	(12.75)
1863-64.........	(8.12)	(8.60)	(8.55)	(8.61)	(7.91)	(8.08)	(9.13)	(9.35)
1864-65.........	(19.91)	(21.10)	(20.98)	(21.12)	(19.40)	(19.82)	(22.39)	(22.94)
1865-66.........	(18.47)	(19.56)	(19.45)	(19.58)	(17.99)	(18.38)	(20.76)	(21.27)
1866-67.........	(28.11)	(29.78)	(29.61)	(29.81)	(27.39)	(27.98)	(31.61)	(32.38)
1867-68.........	(31.28)	(33.14)	(32.95)	(33.17)	(30.47)	(31.13)	(35.17)	(36.02)
1868-69.........	(17.19)	(18.21)	(18.10)	(18.23)	(16.74)	(17.10)	(19.32)	(19.79)
1869-70.........	(15.55)	(16.47)	(16.38)	(16.48)	(15.15)	(15.48)	(17.48)	(17.91)
1870-71.........	(11.36)	(12.04)	(11.97)	(12.05)	(11.07)	(11.31)	(12.78)	(13.09)
1871-72.........	(24.34)	(25.79)	(25.64)	(25.81)	(23.71)	(24.22)	(27.37)	(28.03)
1872-73.........	(13.31)	(14.10)	(14.02)	(14.12)	(12.97)	(13.25)	(14.97)	(15.33)
1873-74.........	(19.21)	(20.35)	(20.23)	(20.37)	(18.71)	(19.11)	(21.59)	(22.12)
1874-75.........	(11.16)	(11.82)	(11.75)	(11.83)	(10.87)	(11.10)	(12.54)	(12.85)
1875-76.........	(23.86)	(25.27)	(25.13)	(25.30)	(23.24)	(23.74)	(26.82)	(27.48)
1876-77.........	(6.60)	(6.99)	(6.96)	(7.00)	(6.43)	(6.57)	(7.42)	(7.60)
1877-78.........	(21.26)	(22.53)	(22.40)	(22.55)	(20.72)	(21.16)	(23.91)	(24.49)
1878-79.........	(15.78)	(16.71)	(16.62)	(16.73)	(15.37)	(15.70)	(17.74)	(18.17)
1879-80.........	(17.35)	(18.38)	(18.28)	(18.40)	(16.91)	(17.27)	(19.51)	(19.99)
1880-81.........	(16.70)	(17.70)	(17.59)	(17.71)	(16.27)	(16.62)	(18.78)	(19.24)
1881-82.........	(14.68)	(15.56)	(15.47)	(15.57)	(14.30)	(14.61)	(16.51)	(16.91)
1882-83.........	(16.08)	(17.04)	(16.94)	(17.05)	(15.67)	(16.00)	(18.08)	(18.52)
1883-84.........	(26.94)	(28.54)	(28.38)	(28.57)	(26.25)	(26.81)	(30.29)	(31.03)
1884-85.........	(16.11)	(17.07)	(16.97)	(17.09)	(15.70)	(16.03)	(18.12)	(18.56)
1885-86.........	(20.67)	(21.90)	(21.78)	(21.93)	(20.14)	(20.57)	(23.25)	(23.81)
1886-87.........	(13.39)	(14.19)	(14.11)	(14.20)	(13.05)	(13.33)	(15.06)	(15.42)
1887-88.........	(15.01)	(15.90)	(15.81)	(15.92)	(14.62)	(14.94)	(16.87)	(17.29)
1888-89.........	(15.48)	(16.40)	(16.31)	(16.42)	(15.08)	(15.41)	(17.41)	(17.83)
1889-90.........	(32.54)	(34.47)	(34.27)	(34.51)	(31.70)	(32.38)	(36.59)	(37.48)
1890-91.........	(14.80)	(15.68)	(15.59)	(15.70)	(14.42)	(14.73)	(16.64)	(17.05)
1891-92.........	(16.60)	(17.59)	(17.49)	(17.61)	(16.18)	(16.52)	(18.67)	(19.12)
1892-93.........	(25.33)	(26.84)	(26.69)	(26.87)	(24.68)	(25.21)	(28.49)	(29.18)
1893-94.........	(18.68)	(19.79)	(19.68)	(19.81)	(18.20)	(18.59)	(21.01)	(21.51)
1894-95.........	(24.84)	(26.32)	(26.17)	(26.34)	(24.20)	(24.72)	(27.93)	(28.61)
1895-96.........	(17.49)	(18.53)	(18.43)	(18.55)	(17.04)	(17.41)	(19.67)	(20.15)
1896-97.........	(19.98)	(21.17)	(21.05)	(21.19)	(19.47)	(19.89)	(22.47)	(23.02)
1897-98.........	(10.12)	(10.72)	(10.66)	(10.73)	(9.86)	(10.07)	(11.38)	(11.66)
1898-99.........	(13.69)	(14.50)	(14.42)	(14.52)	(13.34)	(13.62)	(15.39)	(15.76)
1899-00.........	(17.78)	(18.83)	(18.73)	(18.85)	(17.32)	(17.69)	(19.99)	(20.48)
1900-01.........	(21.43)	(22.70)	(22.58)	(22.73)	(20.88)	(21.33)	(24.10)	(24.69)
1901-02.........	(16.17)	(17.13)	(17.03)	(17.15)	(15.76)	(16.09)	(18.18)	(18.63)
1902-03.........	(16.90)	(17.90)	(17.80)	(17.92)	(16.47)	(16.82)	(19.00)	(19.46)
1903-04......... } 1904-05.........	36.51	38.67	38.46	38.73	35.58	36.33	41.08	42.06
1905-06.........	(21.29)	(22.56)	(22.43)	(22.58)	(20.75)	(21.19)	(23.94)	(24.53)
1906-07.........	(25.65)	(27.18)	(27.02)	(27.20)	(24.99)	(25.53)	(28.84)	(29.54)
1907-08.........	(12.73)	(13.49)	(13.41)	(13.50)	(12.40)	(12.67)	(14.32)	(14.66)
1908-09.........	(21.36)	(22.63)	(22.50)	(22.66)	(20.81)	(21.26)	(24.02)	(24.61)
1909-10.........	(16.36)	(17.33)	(17.23)	(17.35)	(15.94)	(16.28)	(18.39)	(18.84)
1910-11.........	(20.74)	(21.98)	(21.85)	(22.00)	(20.21)	(20.64)	(23.32)	(23.89)
1911-12.........	(10.82)	(11.46)	(11.41)	(11.48)	(10.54)	(10.77)	(12.17)	(12.46)
Mean	18.37	19.46	19.35	19.48	17.90	18.28	20.66	21.16

SIXTY-THREE YEAR RAINFALL RECORD EXPANDED BY COMPARISON WITH SAN FRANCISCO.

	Westley	Gilroy	Pleasanton (S. V. W. Co.) (2)	Pleasanton (S. P. R. R.) (1)	Sunol (4)
1849-50............	(14.18)	(28.62)	(36.77)	(24.05)	(31.34)
1850-51............	(3.18)	(6.42)	(8.24)	(5.39)	(7.02)
1851-52............	(7.91)	(15.96)	(20.51)	(13.41)	(17.48)
1852-53............	(15.11)	(30.48)	(39.18)	(25.61)	(33.39)
1853-54............	(10.23)	(20.64)	(26.52)	(17.34)	(22.60)
1854-55............	(10.18)	(20.54)	(26.40)	(17.25)	(22.50)
1855-56............	(9.28)	(18.72)	(24.07)	(15.73)	(20.51)
1856-57............	(8.53)	(17.21)	(22.13)	(14.46)	(18.86)
1857-58............	(9.35)	(18.86)	(24.24)	(15.84)	(20.65)
1858-59............	(9.53)	(19.23)	(24.70)	(16.15)	(21.05)
1859-60............	(9.54)	(19.26)	(24.75)	(16.18)	(21.09)
1860-61............	(8.44)	(17.03)	(21.87)	(14.30)	(18.64)
1861-62............	(21.11)	(42.60)	(54.76)	(35.79)	(46.66)
1862-63............	(5.89)	(11.88)	(15.27)	(9.98)	(13.02)
1863-64............	(4.32)	(8.72)	(11.21)	(7.32)	(9.55)
1864-65............	(10.60)	(21.39)	(27.49)	(17.97)	(23.42)
1865-66............	(10.44)	(21.07)	(25.49)	(17.71)	(21.72)
1866-67............	(14.96)	(30.20)	(38.80)	(25.37)	(33.06)
1867-68............	(16.64)	(33.58)	(43.17)	(28.21)	(36.79)
1868-69............	(9.17)	(18.50)	(23.72)	(15.54)	(20.21)
1869-70............	(8.61)	(17.37)	(21.46)	(14.59)	(18.29)
1870-71............	(8.07)	(12.20)	(15.68)	(10.25)	(13.36)
1871-72............	(13.00)	(26.22)	(33.59)	(22.03)	(28.63)
1872-73............	(7.07)	(14.26)	(18.36)	(11.99)	(15.66)
1873-74............	(10.22)	(20.62)	(26.51)	(17.33)	(22.59)
1874-75............	(5.85)	15.12	(15.39)	(9.92)	(13.12)
1875-76............	(12.70)	31.04	(32.93)	(21.53)	(28.06)
1876-77............	(3.52)	6.53	(9.11)	(5.96)	(7.77)
1877-78............	(4.13)	28.03	(29.35)	(19.19)	(25.01)
1878-79............	(8.40)	16.76	(21.77)	(14.24)	(18.56)
1879-80............	(9.24)	22.38	(23.95)	(15.56)	(20.41)
1880-81............	(8.87)	23.42	(23.05)	(15.06)	(19.64)
1881-82............	(7.81)	14.09	(20.26)	(13.23)	(17.27)
1882-83............	(8.55)	15.19	(22.20)	(14.49)	(18.91)
1883-84............	(14.32)	24.60	(37.05)	(24.28)	(31.69)
1884-85............	(8.57)	14.74	(22.24)	(14.52)	(18.95)
1885-86............	(10.99)	21.45	(28.53)	(18.63)	(24.32)
1886-87............	(7.11)	11.11	(18.48)	(12.05)	(15.75)
1887-88............	(7.98)	16.78	(20.71)	(13.52)	(17.65)
1888-89............	4.60	14.44	(21.37)	(13.95)	(18.21)
1889-90............	17.01	37.75	(44.91)	(30.33)	38.99
1890-91............	7.09	14.84	(20.43)	(13.34)	14.05
1891-92............	8.98	18.91	(22.92)	(14.95)	16.54
1892-93............	14.65	24.50	(34.97)	(22.83)	27.19
1893-94............	7.62	12.91	(25.79)	(17.47)	21.72
1894-95............	13.92	28.81	(34.29)	(22.39)	27.02
1895-96............	10.44	24.70	(24.14)	(15.77)	17.59
1896-97............	14.06	21.82	(27.58)	(18.02)	22.22
1897-98............	4.18	10.44	(13.97)	(9.11)	10.51
1898-99............	7.84	19.44	(18.89)	(12.33)	20.41
1899-00............	10.14	14.54	22.52	(16.02)	22.27
1900-01............	13.71	23.17	31.68	(19.31)	25.57
1901-02............	7.87	18.41	21.14	(14.83)	19.46
1902-03............	11.08	17.48	22.30	(15.24)	19.02
1903-04............	7.68	18.26	26.92	(14.64)	22.16
1904-05............	11.65	23.25	23.82	(18.33)	23.29
1905-06............	13.18	29.42	29.16	(19.19)	25.21
1906-07............	16.87	28.98	32.03	22.94	29.78
1907-08............	7.64	14.25	15.85	9.97	16.70
1908-09............	9.78	27.81	31.14	20.63	25.18
1909-10............	8.91	19.47	22.20	15.06	18.53
1910-11............	12.84	19.38	32.39	20.12	28.43
1911-12............	8.47	13.87	16.57	9.61	15.81
Mean..........	9.91	20.15	25.29	16.56	21.58

SIXTY-THREE YEAR RAINFALL RECORD EXPANDED BY COMPARISON WITH SAN FRANCISCO.

	Skunk Hollow (44)	San Felipe (18)	San Felipe (17)	San Felipe (32)	Arroyo Valle (34)	Arroyo Valle (37)	Upper Alameda (12)
1849-50.........	(39.04)	(35.96)	(39.29)	(33.55)	(25.58)	(24.42)	(39.26)
1850-51.........	(8.75)	(8.06)	(8.80)	(7.52)	(5.73)	(5.47)	(8.80)
1851-52.........	(21.77)	(20.06)	(21.91)	(18.71)	(14.27)	(13.62)	(21.90)
1852-53.........	(41.59)	(38.32)	(41.86)	(35.75)	(27.26)	(26.01)	(41.83)
1853-54.........	(28.15)	(25.94)	(28.33)	(24.20)	(18.45)	(17.61)	(28.31)
1854-55.........	(28.02)	(25.82)	(28.20)	(24.09)	(18.36)	(17.53)	(28.18)
1855-56.........	(25.55)	(23.54)	(25.72)	(21.97)	(16.75)	(15.98)	(25.70)
1856-57.........	(23.49)	(21.64)	(23.64)	(20.19)	(15.39)	(14.69)	(23.62)
1857-58.........	(25.73)	(23.70)	(25.89)	(22.11)	(16.86)	(16.09)	(25.87)
1858-59.........	(26.22)	(24.15)	(26.39)	(22.53)	(17.18)	(16.40)	(26.37)
1859-60.........	(26.27)	(24.21)	(26.44)	(22.58)	(17.22)	(16.43)	(26.43)
1860-61.........	(23.21)	(21.39)	(23.36)	(19.95)	(15.21)	(14.52)	(23.35)
1861-62.........	(58.16)	(53.54)	(58.50)	(49.96)	(38.09)	(36.35)	(58.46)
1862-63.........	(16.21)	(14.94)	(16.32)	(13.94)	(10.62)	(10.14)	(16.31)
1863-64.........	(11.90)	(10.96)	(11.97)	(10.23)	(7.80)	(7.44)	(11.96)
1864-65.........	(29.18)	(26.88)	(29.36)	(25.08)	(19.12)	(18.25)	(29.34)
1865-66.........	(27.05)	(24.93)	(27.23)	(23.25)	(17.73)	(16.92)	(27.21)
1866-67.........	(41.19)	(37.95)	(41.45)	(35.40)	(26.99)	(25.76)	(41.42)
1867-68.........	(45.82)	(42.21)	(46.12)	(39.39)	(30.03)	(28.67)	(46.09)
1868-69.........	(25.18)	(23.20)	(25.34)	(21.64)	(16.50)	(15.75)	(25.32)
1869-70.........	(22.78)	(20.99)	(22.93)	(19.58)	(14.93)	(14.25)	(22.91)
1870-71.........	(16.64)	(15.34)	(16.75)	(14.31)	(10.91)	(10.41)	(16.74)
1871-72.........	(35.66)	(32.85)	(35.89)	(30.65)	(23.37)	(22.30)	(35.86)
1872-73.........	(19.50)	(17.97)	(19.63)	(16.77)	(12.78)	(12.20)	(19.62)
1873-74.........	(28.14)	(25.92)	(28.32)	(24.09)	(18.44)	(17.60)	(28.30)
1874-75.........	(16.34)	(15.06)	(16.45)	(14.05)	(10.71)	(10.22)	(16.44)
1875-76.........	(34.95)	(32.20)	(35.18)	(30.04)	(22.90)	(21.86)	(35.15)
1876-77.........	(9.67)	(8.91)	(9.74)	(8.31)	(6.34)	(6.05)	(9.73)
1877-78.........	(31.16)	(28.70)	(31.36)	(26.78)	(20.42)	(19.49)	(31.33)
1878-79.........	(23.11)	(21.29)	(23.26)	(19.87)	(15.15)	(14.46)	(23.25)
1879-80.........	(25.42)	(23.42)	(25.59)	(21.85)	(16.66)	(15.90)	(25.57)
1880-81.........	(24.47)	(22.54)	(24.63)	(21.03)	(16.04)	(15.31)	(24.61)
1881-82.........	(21.51)	(19.82)	(21.65)	(18.49)	(14.10)	(13.45)	(21.63)
1882-83.........	(23.56)	(21.71)	(23.71)	(20.25)	(15.44)	(14.74)	(23.70)
1883-84.........	(39.47)	(36.36)	(39.73)	(33.93)	(25.86)	(24.69)	(39.70)
1884-85.........	(23.60)	(21.75)	(23.76)	(20.29)	(15.47)	(14.76)	(23.74)
1885-86.........	(30.29)	(27.90)	(30.48)	(26.04)	(19.85)	(18.94)	(30.46)
1886-87.........	(19.62)	(18.08)	(19.75)	(16.86)	(12.86)	(12.27)	(19.73)
1887-88.........	(21.99)	(20.26)	(22.13)	(18.90)	(14.41)	(13.75)	(22.11)
1888-89.........	(22.68)	(20.90)	(22.83)	(19.50)	(14.86)	(14.19)	(22.81)
1889-90.........	(47.67)	(43.92)	(47.98)	(40.98)	(31.24)	(29.82)	(47.95)
1890-91.........	(21.68)	(19.98)	(21.82)	(18.64)	(14.21)	(13.56)	(21.81)
1891-92.........	(24.33)	(22.41)	(24.48)	(20.91)	(15.94)	(15.22)	(24.47)
1892-93.........	(37.12)	(34.20)	(37.36)	(31.90)	(24.32)	(23.22)	(37.33)
1893-94.........	(27.37)	(25.22)	(27.55)	(23.53)	(17.94)	(17.12)	(27.53)
1894-95.........	(36.40)	(33.53)	(36.63)	(31.28)	(23.85)	(22.76)	(36.60)
1895-96.........	(25.62)	(23.61)	(25.79)	(22.03)	(16.79)	(16.03)	(25.77)
1896-97.........	(29.28)	(26.97)	(29.47)	(25.17)	(19.19)	(18.31)	(29.45)
1897-98.........	(14.83)	(13.66)	(14.92)	(12.74)	(9.72)	(9.27)	(14.91)
1898-99.........	(20.05)	(18.48)	(20.18)	(17.24)	(13.14)	(12.54)	(20.17)
1899-00.........	(26.04)	(23.99)	(26.21)	(22.39)	(17.07)	(16.29)	(26.19)
1900-01.........	(31.40)	(28.93)	(31.60)	(26.99)	(20.58)	(19.64)	(31.58)
1901-02.........	(23.69)	(21.83)	(23.84)	(20.36)	(15.52)	(14.82)	(23.83)
1902-03.........	(24.76)	(22.81)	(24.92)	.....	(16.22)	(15.49)	(24.90)
1903-04.........	26.75	49.28	53.84	57.63	.....	.....	.....
1904-05.........	(29.80)	.....	(29.99)	.....	35.05	33.45	53.81
1905-06.........	(31.20)	(28.74)	.....	(26.82)	(20.44)	(19.51)	(31.38)
1906-07.........	(37.58)	(34.62)	(37.82)	(32.30)	(24.62)	(23.50)	(37.80)
1907-08.........	(18.65)	(17.18)	(18.77)	(16.03)	(12.22)	(11.67)	(18.76)
1908-09.........	(31.30)	(28.84)	(31.50)	(26.90)	(20.51)	(19.58)	(31.48)
1909-10.........	(23.96)	(22.08)	(24.12)	(20.60)	(15.70)	(14.99)	(24.10)
1910-11.........	(30.39)	(28.00)	(30.59)	(26.12)	(19.91)	(19.01)	(30.57)
1911-12.........	(15.85)	(14.60)	(15.95)	(13.63)	(10.38)	(9.91)	(15.94)
Mean	26.96	24.79	27.07	22.98	17.63	16.82	27.07

Distribution of Normal Rainfall.

The normal rainfall at these stations was used to locate the position of some of the isohyetal lines also plotted on Map (Plate A 2). In plotting the isohyetal lines in such portions of the drainage areas, where no rainfall records existed or were available, consideration was given to the topography of the land, and to the character of its vegetation, as well as to the rate of increase or diminution of rainfall in the mountainous regions due to altitude.

The isohyetals plotted are lines of equal mean rainfall. The rainfall is for the period of 63 years. The mean area rainfall over each watershed or drainage area of the Alameda System, as well as for the entire Alameda System, was computed with a planimeter, by determining the area between lines of rainfall and assuming the mean between two lines bounding that area as the mean rainfall to be applied to the area.

The cubical quantities of precipitation thus computed for each watershed or drainage area were added together and the total sum divided by the area of that watershed or drainage area. The resulting quotient was taken as the mean area rainfall for that portion of the Alameda System.

In like manner the mean area rainfall for the 63 year period for each watershed or subdivision of the Alameda system, as well as the entire system was computed, and is as follows:

Name of Drainage Area.	Area in Sq. Miles.	Mean area rainfall for 63 year period. In inches.
Calaveras Creek	98.30	28.55
Upper Alameda	35.32	27.75
San Antonio	38.70	23.93
Arroyo Valle	140.80	20.80
Drainage to Sunol Gravels	49.08	23.00
Livermore Gravels Drainage, including Arroyo Mocho and floor of Valley	258.34	18.55
Total Area	620.54	21.84

Mean Area Rainfall for Subsidiary Catchment Areas.

The mean area rainfall of the Alameda System of 21.84 inches was found by comparison with the means at various stations to approximate the mean of the means of two stations, viz.:

	Inches.
Calaveras	26.73
Livermore	15.95
2 |	42.68
	21.34

This mean of 21.34 inches so closely approximated, the mean area rainfall of the Alameda System drainage area of 21.84 inches that these stations were used as a base from which to estimate from the mean of their means the probable mean area rainfall for each year over the entire Alameda System.

In like manner the mean area rainfall over each subdivision of the Alameda System was compared with the mean of stations within or in the vicinity of its area.

In estimating the probable mean area rainfall over the Calaveras watershed of 98.3 sq. miles, for each season of the 63 year period, the relation existing between the mean area rainfall of the Calaveras watershed (28.55 inches), and the mean of the means of the records at the Calaveras Reservoir 26.73, and at Lick Observatory 31.88 was found to closely approximate the mean area rainfall over the Calaveras drainage area, and the means of these two stations for each year of the 63 year period was assumed to represent for each year the probable mean area rainfall over the Calaveras drainage.

Similarly for the probable mean area rainfall over the upper Alameda watershed of 35.32 sq. miles, for each season of the 63 year period, the record of the Calaveras Reservoir was used, without modification, since it was found by comparison that the mean area rainfall of the Alameda watershed of 27.75 inches closely approximated the mean of the record at the Calaveras Reservoir of 26.73 inches.

In like manner it was found by comparison that the mean area rainfall of 23.93 inches for the San Antonio watershed (area 38.70 sq. miles), closely approximated the mean of the means of the Calaveras (26.73) and the Sunol Station (21.58). Therefore the mean of each season's record at these two stations was applied, as representing the probable mean area rainfall over the San Antonio watershed for that season.

In estimating the probable mean rainfall over the Sunol drainage (49.08 square miles) for each season of the 63 year period, the mean between the records at Sunol and at the Spring Valley Pleasanton Station was applied as representing the mean area rainfall over the Sunol drainage for that season. The two stations, viz.: Sunol and Pleasanton (S. V. W. Co.) combined, were used as a base for the Sunol drainage for the

TABLE SHOWING ESTIMATED MEAN AREA RAINFALL, IN INCHES, FOR EACH YEAR OF THE 63-YEAR PERIOD FROM 1849-50 TO 1911-12 ON EACH OF THE SUBDIVISIONS, AS WELL AS THE WHOLE OF THE ALAMEDA SYSTEM.

ALAMEDA SYSTEM, 620.5 SQUARE MILES.

Season.	Calaveras (98.3 sq. mi.)	Upper Alameda (35.32 sq. mi.)	San Antonio (38.70 sq. mi.)	Sunol Drainage (49.08 sq. mi.)	Arroyo Valle (140.80 sq. mi.)	Livermore Drainage (258.34 sq. mi.)
1849-50	42.54	38.83	35.08	34.05	31.00	27.07
1850-51	9.53	8.70	7.86	7.63	6.94	6.06
1851-52	23.73	21.65	19.56	18.99	17.28	15.09
1852-53	45.32	41.36	37.37	36.28	33.02	28.83
1853-54	30.68	28.00	25.30	24.56	22.35	19.52
1854-55	30.53	27.87	25.18	24.45	22.25	19.43
1855-56	27.83	25.41	22.96	22.29	20.28	17.71
1856-57	25.58	23.35	21.10	20.49	18.64	16.28
1857-58	28.04	25.58	23.11	22.44	20.42	17.83
1858-59	28.57	26.06	23.55	22.87	20.80	18.17
1859-60	28.62	26.12	23.60	22.92	20.85	18.21
1860-61	25.35	23.13	20.88	20.25	18.46	16.02
1861-62	63.32	57.80	52.23	50.71	46.14	40.30
1862-63	17.66	16.12	14.57	14.14	12.87	11.24
1863-64	12.96	11.82	10.68	10.38	9.44	8.24
1864-65	31.79	29.01	26.21	25.45	23.16	20.23
1865-66	29.47	26.90	24.31	23.60	21.47	18.76
1866-67	44.88	40.96	37.01	35.93	32.70	28.56
1867-68	49.91	45.56	41.17	39.98	36.37	31.76
1868-69	27.43	25.04	22.62	21.96	19.99	17.46
1869-70	24.82	22.65	20.47	19.87	18.08	15.79
1870-71	18.13	16.55	14.95	14.52	13.21	11.54
1871-72	39.25	35.50	32.06	31.11	27.28	24.87
1872-73	20.13	18.37	17.01	17.01	14.53	12.81
1873-74	31.79	29.01	25.80	24.55	20.63	20.23
1874-75	17.50	16.28	14.70	14.25	13.97	11.39
1875-76	40.05	40.50	34.28	30.49	30.24	26.80
1876-77	11.19	12.15	9.96	8.44	9.08	7.87
1877-78	33.69	29.02	27.01	27.18	23.34	20.65
1878-79	26.03	21.43	19.99	20.16	15.77	15.12
1879-80	28.21	27.69	24.05	22.18	21.83	18.78
1880-81	25.91	25.03	22.33	21.34	20.74	17.31
1881-82	25.73	22.32	19.79	18.76	17.01	15.05
1882-83	29.33	21.40	20.15	20.55	17.63	14.76
1883-84	47.67	37.26	34.47	34.37	30.00	25.74
1884-85	32.15	19.63	19.29	20.59	15.83	13.68
1885-86	31.54	31.66	27.99	26.42	23.91	21.94
1886-87	21.51	18.94	17.34	17.11	15.05	13.21
1887-88	25.65	21.28	19.46	19.18	17.20	14.84
1888-89	20.86	19.87	19.04	19.79	17.84	15.17
1889-90	45.35	45.54	42.26	41.95	37.10	34.60
1890-91	22.14	20.23	17.14	17.24	17.19	14.95
1891-92	26.36	25.24	20.89	19.73	19.74	17.16
1892-93	38.56	39.20	33.19	31.08	32.74	27.74
1893-94	33.32	30.81	26.26	23.75	23.98	17.84
1894-95	37.62	38.63	32.82	30.65	31.50	26.37
1895-96	27.79	25.82	21.70	20.86	21.08	18.02
1896-97	31.71	31.20	26.71	24.90	24.24	21.23
1897-98	15.51	13.37	11.94	12.24	11.24	9.52
1898-99	23.35	20.98	20.69	19.65	15.62	13.60
1899-00	27.57	25.84	24.05	22.39	19.28	18.71
1900-01	31.15	30.66	28.11	28.62	25.19	21.37
1901-02	25.44	23.27	21.36	20.30	20.03	15.77
1902-03	27.62	24.95	21.98	20.66	19.60	17.10
1903-04	30.63	27.49	24.82	24.54	20.41	17.26
1904-05	28.63	28.72	26.00	23.55	22.26	21.78
1905-06	33.23	28.04	26.62	27.18	23.68	21.38
1906-07	38.16	32.98	31.38	30.90	28.06	24.48
1907-08	20.63	17.34	17.02	16.27	13.63	12.51
1908-09	34.22	31.02	28.10	28.16	24.80	21.26
1909-10	25.21	24.41	21.47	20.36	19.45	17.12
1910-11	30.70	28.12	28.27	30.41	24.70	19.74
1911-12	16.51	14.79	15.30	16.19	12.14	10.75
Mean	29.31	26.73	24.17	23.47	21.35	18.65
Calculated from Isohyetal Map	28.55	27.75	23.93	23.00	20.80	18.55
Mean for last 23 years	29.19	28.64	24.70	23.98	22.07	19.16

reason that the mean of their rainfall for the 63 year period, 21.58 inches and 25.29 inches respectively, or 23.43 inches, corresponds closely with the mean area rainfall over the Sunol drainage, of 23.00 inches.

The mean of the means for the 63 year period (Calaveras Station, 26.73 inches, and Newman, 10.56 inches), of 18.64 inches, so closely corresponds with the mean area rainfall over the Livermore Valley drainage (258.34 square miles) of 18.55 inches, that the mean rainfall for these two stations, for each season of the 63 year period was taken to represent the probable mean area rainfall for the Livermore catchment area for that season.

An estimate was also made of the probable seasonal rainfall for each season of the 63 year period over the Arroyo Valle watershed of 140.80 sq. miles. The relation existing between the mean area rainfall for the 63 year period over the Arroyo Valle watershed of 20.80 inches as compared with the mean of the means for the same period at Calaveras (26.73) and Livermore (15.95) or 21.34, is such that the mean of these two stations for each year was applied as the probable mean area rainfall over the Arroyo Valle watershed for the corresponding season.

Using the various means above indicated, each for its respective subsidiary catchment area, in the manner above described, the area rainfall for each of the 63 seasons, beginning with the season 1849-50 and ending with the season 1911-12, has been estimated for each subsidiary catchment area. The results of these estimates, given in the foregoing table, have been used in conjunction with available run-off data to determine the distribution of the water crop of the Alameda System:

Appendix B.

THE WATER PRODUCT OF THE ALAMEDA SYSTEM

REPORT ON THE RUN-OFF FROM THE ALAMEDA WATERSHED

BY

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Assistant Engineer Spring Valley Water Company.

Run-off is the measure of the available, dependable quantity of water, year after year, which may be utilized. Its origin is rainfall, which escapes from the ground upon which it falls, in four ways, viz.: through evaporation, surface run-off, seepage run-off and percolation.

The portion of rainfall which escapes by evaporation is that quantity which passes into the atmosphere in the form of vapor from water and soil surfaces, and from objects resting upon such surfaces, including vegetation. The loss due to evaporation from water surfaces cannot be prevented, nor is it recoverable.

Rainfall which escapes by surface run-off is the amount which, from the time of falling until its exit from the drainage area on which it falls, passes over the surface without entering into the ground.

Rainfall which escapes through seepage run-off, is that which sinks into the soil, but which later reappears on the surface at lower altitudes and becomes a part of the surface run-off. Its extent is not directly measurable, and, in this discussion, it is included in the surface run-off.

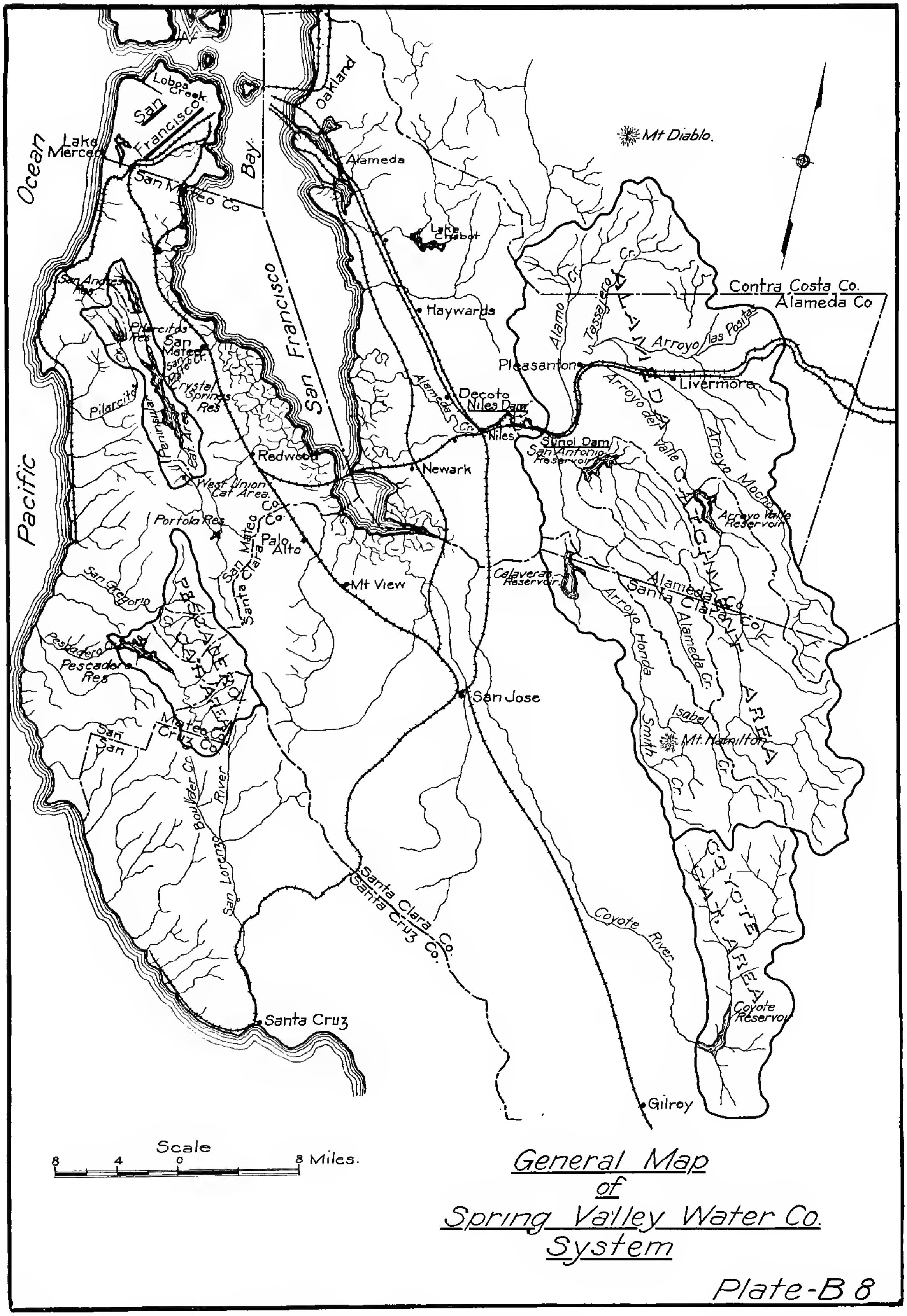
Run-off which escapes through percolation passes below the soil surface, by seepage into the soil pores, and becomes thereby a part of the underground waters.

Of these three natural subdivisions of rainfall—evaporation, surface run-off and percolation—only the surface run-off is easily measurable. Surface run-off, appearing in natural water courses which drain the area or source of the run-off, is generally styled the stream discharge or stream flow of that water course or of the area which is drained by that water course. The amount of the stream flow is measured by gagings, and wherever available, reliable stream gagings, covering a period of years, are the best index of the quantity of water that may be relied upon from the catchment area above the place of measurement.

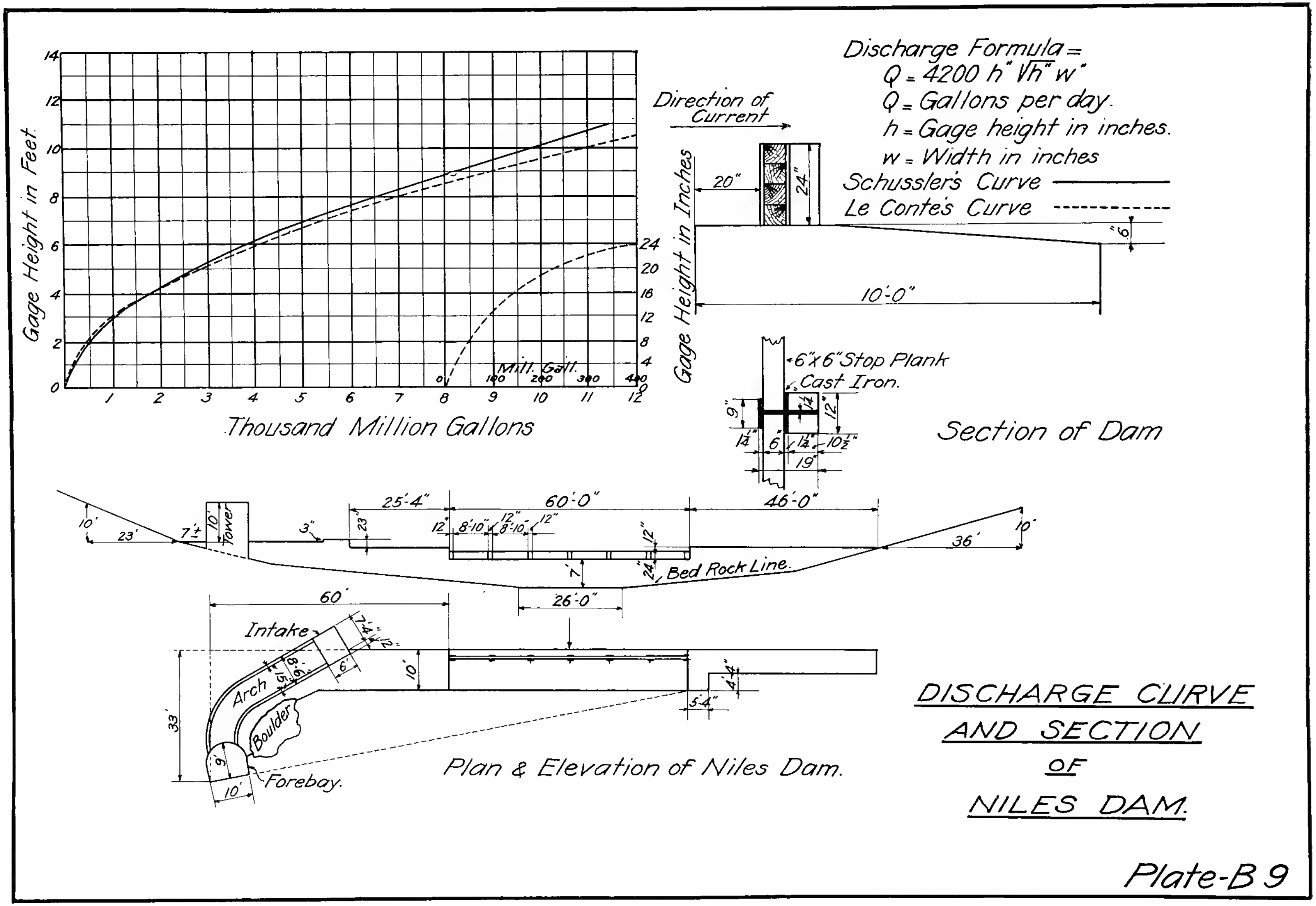
Available Stream Gagings.

The Alameda System of the Spring Valley Water Company represents the summation of increments that have been added from time to time since 1875. Its acquirement has been the product of careful thought and investigation, commencing with the Calaveras Reservoir, and followed by such steps and acquisitions as diversion from Alameda Creek above Niles, the utilization of the Sunol Filter Beds, the San Antonio Reservoir, the Arroyo Valle Reservoir, underground development at Pleasanton and at Sunol. These have followed in natural sequence, by reason of the far-sighted policy of the Spring Valley Water Company, the cardinal factor of which is to secure opportunities for extensive development in advance of actual needs—that the people of San Francisco will always have at hand an abundant supply of pure, wholesome water.

Under these circumstances, it is not to be expected that there should be complete and ex-



THE WATER RESOURCES OF THE SPRING VALLEY WATER COMPANY ARE ALL LOCATED NEAR SAN FRANCISCO.



Scientific investigation by Prof. Le Conte shows that previous stream measurements at Niles Dam by Spring Valley Water Company were conservative,

act run-off data, covering all the component parts for a long period of time. Available data, from which run-off in the Alameda System may be computed, are as follows:

Flow Measured at Niles, Sunol, Calaveras and Arroyo Valle.

Daily gage heights kept at the Niles Dam from 1888 to 1900.

At the Sunol Dam, which succeeded the Niles Dam as the point of diversion of the Alameda waters in 1900, daily gage heights, during low water, and more often during floods have been taken to date.

These two dams were built primarily for diversion purposes and not for stream gaging.

At Calaveras particular attention was paid to stream gagings. Available measurements were taken from 1898 to 1904 by Mr. George Hadsell, and from 1904 to 1908 under the direction of Mr. Cyril Williams, Jr., and during 1910-11 and 1912 by Mr. P. F. Jones.

At the Arroyo Valle damsite, a gaging station was established in 1904, and measurements were made for the seasons of 1904-5 to 1907-8. All of these records are not now among the records of the Spring Valley Water Company. Some months ago I was advised by Mr. Cyril Williams, Jr., formerly in the employ of the Spring Valley Water Company, that it is his belief that some of them were destroyed in the fire of 1906. Fortunately, however, I have been able to secure duplicates of most of the gaging records from Mr. Gainor, who made the measurements and preserved a copy of a portion of the records.

Gagings taken at a point in the Upper Alameda just above its junction with the Calaveras are available for a portion of the season 1910-11 and all of the season 1911-12.

At the San Antonio damsite gagings covering the flood months of the season 1911-12 are available.

Measurement of Alameda Creek Begun at Niles 23 Years Ago.

The first place where gagings were taken in Alameda Creek was at the Niles Dam, which was constructed in 1888 at a point about 2¼ miles above the town of Niles. It is a low masonry diversion weir, with a system of heavy wooden bulkheads, or flash-boards, surmounting the crest. The position of Niles Dam and its relation to the Alameda System are shown on Plate B-8. The plan and cross-section are shown on Plate B-9.

The catchment area of Alameda Creek, above Niles Dam, is 631.5 square miles.

The purpose of this weir was to divert water from Alameda Creek; diversion at this point and the water right incident thereto date back as early as about 1840.

Original Computations too Conservative.

Judging by the enormous floods, issuing from Alameda Creek as it debouched from the mountains, it was generally known that great torrents passed through Niles Canyon, and the Niles Dam was therefore designed as a massive low structure. For the purpose of obtaining the regimen of the Alameda Creek, a gage rod was installed, and daily readings taken from December, 1889, to October, 1900. Approximate computations of quantities of discharge over Niles Dam have been made from the gage readings, heretofore mentioned, by using a weir formula of the type $Q=Cbh^{3/2}$, with all dimensions in inches, and $C=4,200$, the discharge being in gallons per day. On Plate B-9 is shown the discharge curve of the Niles Dam, based on the above formula. In this formula no provision is made for the velocity of approach, nor for submergence below the dam. It has always been recognized that both these factors enter largely into the determination of flow over this weir, though it was believed that, taken over the wide limits of variation of depths as indicated by the rod readings, omission of the effect of these two factors would give conservative results. That the velocity of approach is a factor that very greatly increases the flow over the dams in Niles Canyon may be judged from the fact that, during the flood of March, 1911, it amounted to fully 13 feet per second, the current being so swift that reliable current meter measurments were impossible. For the purpose of this report more accurate knowledge of the stream flow at Niles Dam was required. Careful analysis indicated that, by reason of the irregularity of the weir crest and cross-section, and the complexity of the problem, a discharge curve, based on purely

theoretical deductions, would give uncertain results. This was equally true of the Sunol Dam.

Flow of Alameda Creek Recomputed From Experiments of Models by Prof. Le Conte.

It was therefore decided to investigate the problem by means of a model weir. The models were exact duplicates of the Niles and Sunol Dams, on a small scale, and the same stream cross-sections for 200 feet above the dams was duplicated in miniature. Extended experiments were made with these models by Professor J. N. Le Conte, the eminent specialist in hydraulics on the Pacific Coast. The experiments were made with various depths of water passing over the models with corresponding velocities of approach and different degrees of submergence.

The height of water over the crest of Niles Dam and its degree of submergence during the high water of the flood of March, 1911, were computed from the data kindly furnished by Messrs. Grunsky, Hyde and Marx, who were investigating the measurements over the Niles and Sunol Dams at the request of J. R. Freeman. The data were obtained by them from surveys made of high water marks left by the flood of March, 1911. Professor Le Conte's report is given in full in Appendix "C", which also gives the computations of discharge for the flood of March, 1911, by channel measurements, showing a substantial check on Prof. LeConte's results for that gage height.

The conditions at Niles Dam at the present time are considerably different from what they were at the time the gagings were taken. Just below the dam, and extending into the stream channel on its left-hand side, is a tunnel dump, which was made a few years ago. The shape of the crest of the dam has changed from what it was at the time the measurements were made. In Professor Le Conte's experiments, the models conformed with the original shape of the crest and the stream channel at that time. Contrary to expectations, the degree of submergence of the Sunol Dam, as computed from observations made by the Spring Valley Water Company at the time of the flood of March, 1911, is greater than that of Niles Dam, as computed from data gathered by Messrs. Grunsky, Hyde and Marx one year subsequent to the same flood. The discharge curves of the Niles and Sunol Dams, developed by Prof. LeConte have been used in this report to determine the stream flow over Niles and Sunol Dams from gage heights in the records of the Spring Valley Water Company. The Niles discharge curve conforms with the only actual discharge measurements made by the United States Geological Survey, and published in Water Supply Paper No. 81, pages 34 to 39.

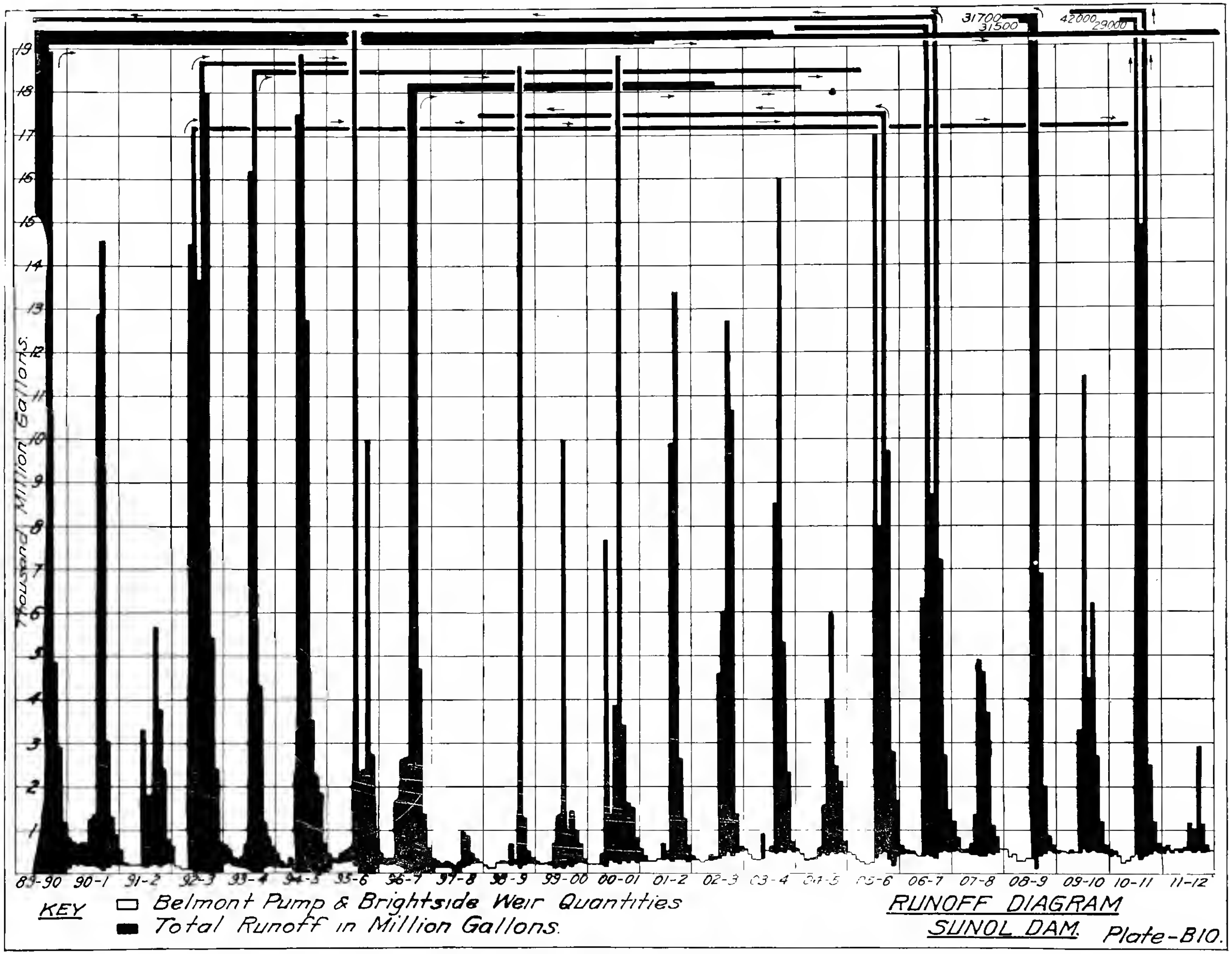
Rod Readings Prove to be an Accurate Index of Total Flow.

It is recognized that rod readings, taken once a day, do not show all the variations in stream flow over a weir, by reason of the fact that the stream may fluctuate considerably between times of observations. This is well illustrated by the following facts regarding the flood over Niles Dam in the early nineties.

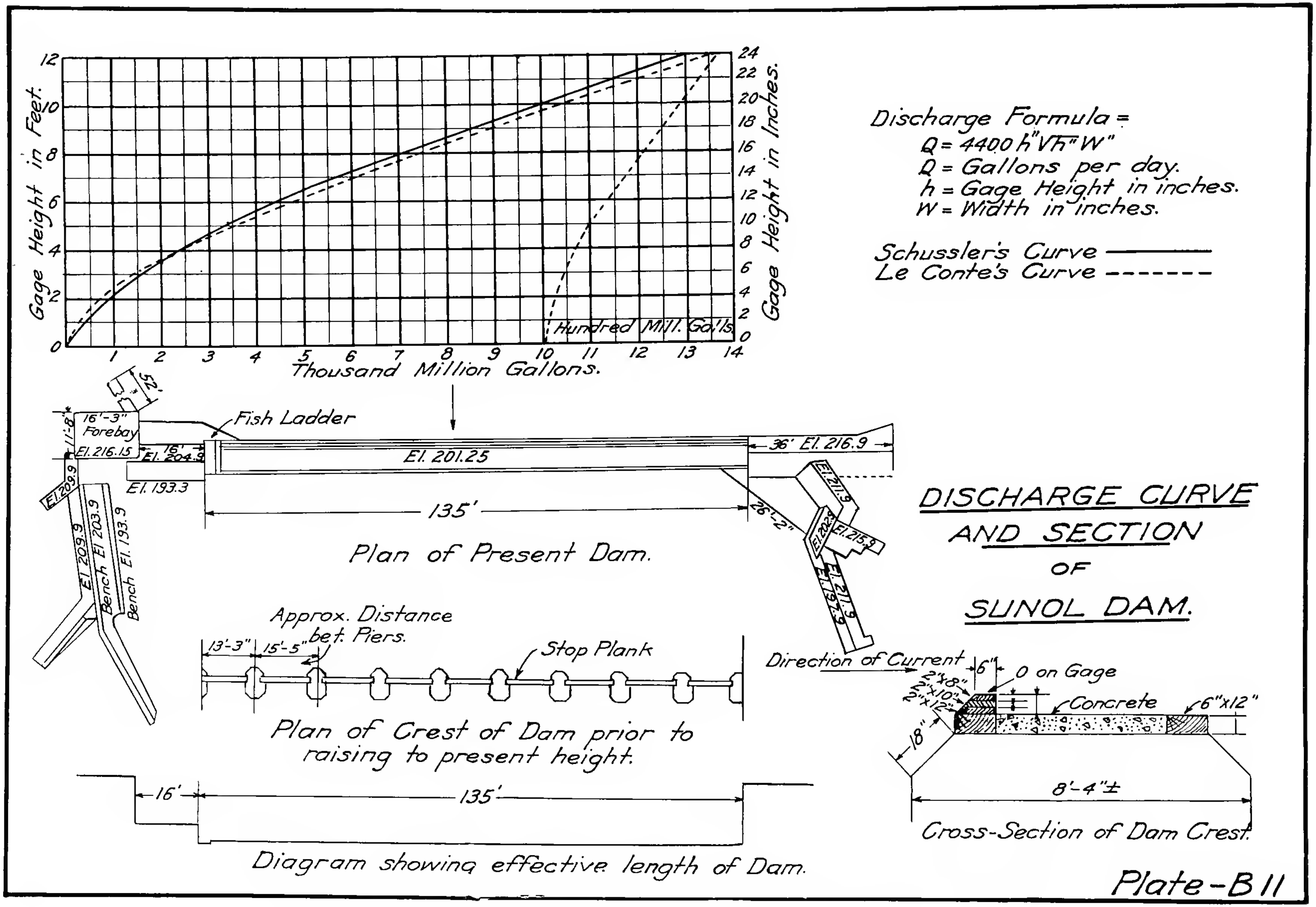
At the regular time of day for taking gage rod readings, Mr. Severance, the watchman, observed the height of the water, and also noted that a large log had been lodged on top of the forebay during the previous night. From this evidence the water had necessarily been several feet higher during the night, but no account was made of this in computing the stream flow. These fluctuations of short duration are of small consequence when compared with the variations over long periods of time, and it is believed that errors due to them compensate throughout a record as long as the one in hand.

This is well illustrated by a comparison of the results of computation of discharge over Sunol Dam, as given in this report, taking into account all variations of gage height during day and night, and a computation over the same period for the same discharge based on one reading a day. For this purpose I have used the gage reading taken at 8 o'clock each morning, just as the records at the Niles Dam were taken, assuming that this reading prevailed throughout the 24 hours.

The results given below show that sometimes one method gives a little higher result than the other, and sometimes the contrary is true, the largest variation in any one season being less than 7%. Taken over the whole 12 years, the result from observations taken once a day is almost identical with that obtained by taking



HYDROGRAPH SHOWING ENORMOUS WASTE WHICH WHEN CONSERVED WILL SUPPLY WATER FOR OVER ONE MILLION PEOPLE.



Prof. Le Conte's investigation shows that average run-off of Alameda Creek is 145 M. G. D.

into account all the fluctuations of the stream height, the latter being 99.8% of the former. These results show that the true discharge over Niles Dam is almost identical with that obtained by computing the flow shown by the daily gage rod readings, as given in this report.

Season	MILLION GALLONS. Computed by considering all minor fluctuations	Computed by taking only one gage reading per day
1900-01	36,848.84	38,217.34
1901-02	27,187.90	27,187.90
1902-03	33,269.30	31,158.70
1903-04	31,000.40	31,000.40
1904-05	15,044.73	15,044.73
1905-06	63,640.24	65,359.37
1906-07	99,228.47	97,004.77
1907-08	14,626.38	14,512.18
1908-09	74,923.85	77,493.28
1909-10	25,931.58	25,365.58
1910-11	87,332.58	87,346.48
1911-12	4,856.04	4,856.04
Total	513,890.31	514,546.77

In order to obtain the run-off available at Niles Dam, or the water crop from the catchment area above Niles Dam, there must be added to the discharge over that dam the amount of water diverted at that structure. Most of this water went to the Belmont Pumps, no account being made of water used between the pumping station and the dam, amounting to about one and one-half million gallons per day at the present time.

On pages 305 to 308 is given a toble which contains the quantity of water that passed over Niles Dam for the period 1889-90 to 1899-1900, as determined by Professor Le Conte's discharge curve, together with the amount that was delivered at the Belmont Pumps during the same period. This is also shown graphically in Plate B 10. For the purpose of this report and that the estimates of water yield may be conservative, the amount used between Niles and Belmont has been neglected.

On Plate B-9 is shown Prof. Le Conte's discharge curve for Niles Dam, together with the discharge curve heretofore used and based on the formula $Q=4{,}200\ bh^{3/2}$, Q being in gallons per day, and b and h in inches.

Flow of Alameda Creek Measured at Sunol Dam Since 1900.

The Sunol Dam was built in 1889, and was changed to its present form in 1900. It is a concrete structure considerably higher and with more regular lines than the Niles Dam, and serves the double purpose of retaining the waters in the Sunol gravel reservoir and of providing a means of conducting the filtered water from the Sunol gravel reservoirs across Alameda Creek. This filtered water is delivered directly into the Niles Aqueduct and the Alameda pipe line. Beginning with the year 1900, the Sunol Dam superseded the Niles Dam as the point of diversion for the water of the Alameda System destined for San Francisco; consequently, the Alameda run-off was measured at the Sunol Dam subsequent to this date.

The location of the Sunol Dam and its relation to the Alameda System are shown on Plate B 8. Plate B 11 shows the plan and cross-section of this dam since gagings have been taken at that point.

During periods of very low water flow, the water surface upstream from the dam is raised slightly by a temporary bulkhead. During such times the water which is in excess of that withdrawn from the gravel reservoir is measured in the fish-ladder. As a matter of fact, the temporary bulkhead, as are all structures of this character, is never completely water-tight, leakage through the same often being equal to that measured in the fish-ladder. No account is kept of this leakage, so that the amount of water which actually passes over Sunol Dam in low water periods is greater than the records indicate.

The catchment area above Sunol Dam is 620.5 square miles, or about 11 square miles less than that above the Niles Dam.

Gage rod readings have been taken at the Sunol Dam from 1900 to date, recording all the fluctuations of Alameda Creek. During times of flood the gage rod has been constantly watched, rod readings being taken often enough to determine all changes in the stages of the creek, the time interval being as low as thirty minutes.

In the case of the Sunol Dam, approximate computations of discharge have heretofore been made by the same type of formula as was used for the Niles Dam, the value of "C" at Sunol being 4,400. Similarly, in computing the discharge over the Sunol Dam, no provision has heretofore been made for velocity of approach nor for submergence. Plate B 11 shows the discharge curve over the Sunol Dam computed

from the formula $Q=4{,}400\ bh^{3/2}$, and on the same Plate is shown the discharge curve for the Sunol Dam as developed by Prof. LeConte's experiments, account being taken of the influence of both the velocity of approach and submergence.

Large Amount of Water Taken From Sunol Gravels.

A large amount of water is extracted from the Sunol underground reservoir above Sunol Dam, whence it is carried through the Niles Canyon Aqueduct on its way to San Francisco. Subsequent to 1900, except in cases of emergency and repair, these waters passed from a large tank at Brightside provided with effective baffles over a battery of four 30″ sharp-edged weirs, where continuous automatic records of depth over the weir have been kept. Excluding the quantity used between Niles and Belmont, and estimated at present to be about one and one-half million gallons per day, all this water passes through the Belmont Pumps, where quantitative records are also kept. Prior to 1903 the record of pumpage at Belmont is the only measure of the amount of water withdrawn from the Sunol gravel reservoir. This, of course, does not include the water used between Niles and Belmont, above mentioned. By combining these two records and neglecting the amount of water diverted between Alameda Creek and Belmont, the total flow from Alameda Creek is determined. The total run-off at Sunol Dam is the sum of the measured run-off over the Sunol Dam and the amount of water flowing through the Niles Aqueduct.

Flow of Alameda Creek for Last 23 Years.

Following is a table of discharges over the Niles Dam from 1889-90 to 1899-1900 and over Sunol Dam from the year 1900 to July 1st, 1912, together with the withdrawal through the Niles Aqueduct, as measured at Belmont Pumps, during the period 1889-90 to April, 1903, and as measured at the Brightside Weir from April, 1903, to July 1st, 1912. By combining these quantities the run-off of Alameda Creek is obtained. This is shown graphically in Plate B 10.

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

JULY.

Season.	Alameda.	Belmont.	Total.
1888-89	0	0	0
1889-90	0	0	0
1890-91	680.00	144.65	824.65
1891-92	287.00	243.64	530.64
1892-93	374.75	243.45	618.20
1893-94	405.25	233.29	638.54
1894-95	261.00	161.94	422.94
1895-96	311.00	86.48	397.48
1896-97	214.50	240.13	454.63
1897-98	318.75	No pump	318.75
1898-99	0	179.70	179.70
1899-00	32.69	231.11	263.80
1900-01	18.66	231.31	249.97
1901-02	226.29	316.58	542.87
1902-03	68.95	325.26	394.21
1903-04	24.06	535.01	559.07
1904-05	23.34	521.39	544.73
1905-06	1.81	508.96	510.77
1906-07	213.74	461.73	675.47
1907-08	633.40	536.64	1,170.04
1908-09	8.90	520.72	529.62
1909-10	91.55	484.03	575.58
1910-11	92.80	446.61	539.41
1911-12	117.80	499.57	617.37

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

AUGUST.

Season.	Alameda.	Belmont.	Total.
1888-89	0	0	0
1889-90	0	0	0
1890-91	487.50	252.53	740.03
1891-92	28.00	227.27	255.27
1892-93	0	181.81	181.81
1893-94	273.25	239.87	513.12
1894-95	78.75	158.53	237.28
1895-96	84.00	240.22	324.22
1896-97	78.75	241.45	320.20
1897-98	129.50	156.35	285.85
1898-99	3.00	143.63	146.63
1890-00	.69	231.07	231.76
1900-01	1.18	231.86	233.04
1901-02	78.22	316.24	394.46
1902-03	31.52	314.69	346.21
1903-04	0	443.66	443.66
1904-05	3.60	469.69	473.29
1905-06	.64	451.26	451.90
1906-07	29.14	494.09	523.23
1907-08	242.20	547.02	789.22
1908-09	4.95	402.18	407.13
1909-10	.24	505.93	506.17
1910-11	24.55	494.31	518.86
1911-12	93.30	527.25	620.55

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

SEPTEMBER.

Season.	Alameda.	Belmont.	Total.
1888-89	0	91.30	91.30
1889-90	0	0	0
1890-91	429.00	236.36	665.36
1891-92	0	200.78	200.78
1892-93	0	126.55	126.55
1893-94	215.00	168.87	383.87
1894-95	25.00	146.15	171.15
1895-96	91.00	229.62	320.62
1896-97	82.25	233.17	315.42
1897-98	69.92	155.92	225.84
1898-99	0	146.58	146.58
1899-00	0	216.81	216.81
1900-01	26.00	196.37	222.37
1901-02	0	288.36	288.36
1902-03	0	271.43	271.43
1903-04	0	356.65	356.65
1904-05	0.48	355.63	356.11
1905-06	0	319.83	319.83
1906-07	12.36	489.09	501.45
1907-08	34.79	512.90	547.69
1908-09	92.50	345.30	437.80
1909-10	3.25	480.00	483.25
1910-11	9.50	401.22	410.72
1911-12	50.70	456.62	507.32

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

OCTOBER.

Season.	Alameda.	Belmont.	Total.
1888-89	0	61.39	61.39
1889-90	0	0	0
1890-91	454.75	242.03	696.78
1891-92	0	205.20	205.20
1892-93	0	126.09	126.09
1893-94	112.00	150.96	262.96
1894-95	187.75	162.01	349.76
1895-96	201.50	237.91	439.41
1896-97	102.29	241.39	343.68
1897-98	101.12	153.75	254.87
1898-99	20.72	206.22	226.94
1899-00	45.00	197.29	242.29
1900-01	188.11	235.86	423.97
1901-02	0	288.54	288.54
1902-03	0	299.40	299.40
1903-04	0	332.81	332.81
1904-05	0.14	364.17	364.31
1905-06	0.03	283.31	283.34
1906-07	.45	459.80	460.25
1907-08	36.52	510.82	547.34
1908-09	3.10	306.12	309.22
1909-10	36.59	499.26	535.85
1910-11	3.89	222.82	226.71
1911-12	40.93	516.46	557.39

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

NOVEMBER.

Season.	Alameda.	Belmont.	Total.
1888-89	0	118.46	118.46
1889-90	0	0	0
1890-91	459.75	235.30	695.05
1891-92	0	198.17	198.17
1892-93	14,372.80	125.91	14,498.71
1893-94	208.00	145.90	353.90
1894-95	153.25	47.33	200.58
1895-96	245.00	232.88	477.88
1896-97	1,479.48	184.49	1,663.97
1897-98	52.50	156.30	208.80
1898-99	18.20	213.18	231.38
1899-00	544.46	112.87	657.33
1900-01	7,520.09	175.25	7,695.34
1901-02	8.12	289.32	297.44
1902-03	104.33	302.30	406.63
1903-04	513.92	382.78	896.70
1904-05	0.34	377.20	377.54
1905-06	0.13	268.50	268.63
1906-07	.45	423.79	424.24
1907-08	182.40	495.12	677.52
1908-09	6.07	286.64	292.71
1909-10	25.97	450.46	476.43
1910-11	4.36	290.32	294.68
1911-12	63.24	491.80	555.04

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

DECEMBER.

Season.	Alameda.	Belmont.	Total
1888-89	0	166.76	166.76
1889-90	36,310.80	No P.	36,310.80
1890-91	1,043.25	204.18	1,247.43
1891-92	3,151.25	190.51	3,341.76
1892-93	39,625.34	50.84	39,676.18
1893-94	508.75	132.06	640.81
1894-95	17,529.15	No. P.	17,529.15
1895-96	305.00	240.69	545.69
1896-97	2,438.82	173.00	2,611.82
1897-98	108.25	43.26	151.51
1898-99	5.63	221.27	226.90
1899-00	2,161.75	134.57	2,296.32
1900-01	989.10	313.54	1,302.64
1901-02	397.82	319.32	717.14
1902-03	13.53	366.65	380.18
1903-04	5.16	504.18	509.34
1904-05	193.48	408.12	601.60
1905-06	1.59	284.93	286.52
1906-07	5,882.03	421.87	6,303.90
1907-08	895.60	476.65	1,372.25
1908-09	22.10	314.43	336.53
1909-10	2,832.52	476.04	3,308.56
1910-11	16.77	426.50	443.27
1911-12	85.80	526.21	612.01

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

JANUARY.

Season.	Alameda.	Belmont.	Total.
1888-89	0	0	0
1889-90	68,825.19	40.50	68,865.69
1890-91	1,141.50	199.02	1,340.52
1891-92	1,594.50	157.53	1,752.03
1892-93	13,519.75	137.23	13,656.98
1893-94	16,162.65	58.31	16,220.96
1894-95	46,689.80	No P.	46,689.80
1895-96	19,286.06	121.28	19,407.34
1896-97	2,639.75	No P.	2,639.75
1897-98	264.23	No P.	264.23
1898-99	480.09	163.14	643.23
1899-00	9,889.15	110.04	9,999.19
1900-01	3,538.40	308.83	3,847.23
1901-02	194.00	320.55	514.55
1902-03	4,028.00	392.43	4,420.43
1903-04	122.16	504.61	626.77
1904-05	1,059.90	481.79	1,541.69
1905-06	16,610.49	360.88	16,971.37
1906-07	21,675.40	470.92	22,146.32
1907-08	4,390.40	456.52	4,846.92
1908-09	31,355.10	332.95	31,688.05
1909-10	10,870.70	595.25	11,465.95
1910-11	28,310.71	485.95	28,796.66
1911-12	696.50	513.62	1,210.12

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

FEBRUARY.

Season.	Alameda.	Belmont.	Total.
1888-89	0	0	0
1889-90	32,833.35	No P.	32,833.35
1890-91	12,751.48	161.74	12,913.22
1891-92	1,567.00	212.92	1,779.92
1892-93	22,016.80	.43	22,017.23
1893-94	33,310.04	No P.	33,310.04
1894-95	12,714.40	No P.	12,714.40
1895-96	2,195.00	No P.	2,195.00
1896-97	25,507.63	No P.	25,507.63
1897-98	827.09	145.46	972.55
1898-99	68.54	205.27	273.81
1899-00	655.75	208.41	864.16
1900-01	18,523.44	256.62	18,780.06
1901-02	9,611.40	290.59	9,901.99
1902-03	5,585.10	435.07	6,020.17
1903-04	8,061.74	451.23	8,512.97
1904-05	3,580.40	436.61	4,017.01
1905-06	7,539.30	455.15	7,994.45
1906-07	8,252.80	463.39	8,716.19
1907-08	4,200.00	468.86	4,668.86
1908-09	31,354.12	144.56	31,498.68
1909-10	4,020.40	506.09	4,526.49
1910-11	14,540.60	350.03	14,890.63
1911-12	576.80	480.70	1,057.50

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

MARCH.

Season.	Alameda.	Belmont.	Total.
1888-89	0	0	0
1889-90	18,987.00	0	18,987.00
1890-91	14,363.67	98.89	14,462.56
1891-92	5,463.50	227.68	5,691.18
1892-93	18,104.50	0	18,104.50
1893-94	4,282.00	18.59	4,300.59
1894-95	3,483.50	0	3,483.50
1895-96	2,377.00	0	2,377.00
1896-97	27,288.00	0	27,288.00
1897-98	658.83	183.83	842.66
1898-99	18,811.68	114.03	18,925.71
1899-00	2,264.00	148.56	2,412.56
1900-01	3,102.70	310.72	3,413.42
1901-02	13,101.40	318.57	13,419.97
1902-03	12,215.80	507.63	12,723.43
1903-04	15,373.80	504.21	15,878.01
1904-05	6,472.60	491.14	6,963.74
1905-06	26,580.72	499.61	27,080.33
1906-07	53,421.10	367.30	53,788.40
1907-08	3,100.10	518.88	3,618.98
1908-09	6,452.10	395.73	6,847.83
1909-10	5,116.70	555.20	5,671.90
1910-11	41,516.50	434.37	41,950.87
1911-12	2,404.18	524.33	2,928.51

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

APRIL.

Season.	Alameda.	Belmont.	Total.
1888-89	0	0	0
1889-90	4,873.00	0	4,873.00
1890-91	2,856.00	193.19	3,049.19
1891-92	3,591.50	176.76	3,768.26
1892-93	5,457.65	0	5,457.65
1893-94	1,032.25	155.39	1,187.64
1894-95	2,194.25	0	2,194.25
1895-96	9,995.78	0	9,995.78
1896-97	4,708.50	0	4,708.50
1897-98	198.15	233.30	431.45
1898-99	1,071.54	190.76	1,262.30
1899-00	722.00	222.47	944.47
1900-01	1,284.80	305.32	1,590.12
1901-02	2,323.40	313.42	2,636.82
1902-03	10,243.98	413.82	10,657.80
1903-04	4,869.60	485.29	5,354.89
1904-05	1,949.70	486.21	2,435.91
1905-06	8,330.95	349.10	8,680.05
1906-07	6,759.80	508.68	7,268.48
1907-08	586.40	505.50	1,091.90
1908-09	1,521.30	474.08	1,995.38
1909-10	2,109.46	542.80	2,652.26
1910-11	1,989.30	482.59	2,471.89
1911-12	600.40	503.52	1,103.92

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

MAY.

Season.	Alameda.	Belmont.	Total.
1888-89..........	0	0	0
1889-90..........	2,886.00	0	2,886.00
1890-91..........	1,153.25	240.99	1,394.24
1891-92..........	2,201.00	221.93	2,422.93
1892-93..........	2,415.00	0	2,415.00
1893-94..........	649.00	161.62	810.62
1894-95..........	1,792.50	0	1,792.50
1895-96..........	2,736.00	0	2,736.00
1896-97..........	1,354.00	0	1,354.00
1897-98..........	65.17	242.05	307.22
1898-99..........	273.59	228.78	502.37
1899-00..........	420.61	232.61	653.22
1900-01..........	1,177.80	317.08	1,494.88
1901-02..........	915.20	324.86	1,240.06
1902-03..........	889.50	499.90	1,389.40
1903-04..........	1,779.50	512.33	2,291.83
1904-05..........	1,580.70	511.18	2,091.88
1905-06..........	2,452.90	164.47	2,617.37
1906-07..........	2,089.20	543.24	2,632.44
1907-08..........	313.80	524.22	838.02
1908-09..........	328.60	530.88	859.48
1909-10..........	666.20	517.54	1,183.74
1910-11..........	665.60	541.72	1,207.32
1911-12..........	121.08	521.75	642.83

RE-COMPUTED FLOW OVER THE NILES AND SUNOL DAM, REPRESENTING THE RUN-OFF OF THE ALAMEDA SYSTEM.

JUNE.

Season.	Alameda.	Belmont.	Total.
1888-89..........	0	0	0
1889-90..........	1,151.25	0	1,151.25
1890-91..........	667.75	234.51	902.26
1891-92..........	526.75	232.17	758.92
1892-93..........	603.75	28.36	632.11
1893-94..........	432.75	156.40	589.15
1894-95..........	636.50	0	636.50
1895-96..........	618.25	131.90	750.15
1896-97..........	564.00	0	564.00
1897-98..........	8.63	225.65	234.28
1898-99..........	102.11	223.44	325.55
1899-00..........	77,17	226.32	303.49
1900-01..........	478.60	306.68	785.28
1901-02..........	332.20	286.96	619.16
1902-03..........	88.84	506.00	594.84
1903-04..........	204.12	496.93	701.05
1904-05..........	180.05	503.05	683.10
1905-06..........	1,218.80	403.17	1,621.97
1906-07..........	892.00	523.97	1,415.97
1907-08..........	10.77	523.84	534.61
1908-09..........	148.00	493.09	641.09
1909-10..........	158.00	480.59	638.59
1910-11..........	158.00	516.21	674.21
1911-12..........	5.31	519.58	524.89

Early Measurement of Calaveras Creek.

Measurements of the flow of Calaveras Creek at the Calaveras Reservoir have been taken during varying intervals of time since 1874.

The first measurements were made by Mr. T. R. Scowden, Engineer for Water Supply Investigation for the City of San Francisco, and cover a period of 120 days in the season 1874-5. The results of these gagings are to be found in the Municipal Report of 1874-5. While this record is only for 120 days, it includes the period of run-off for high flow, as well as the record of rainfall for the same period. Gagings covering the remainder of the season were taken by the Spring Valley Water Company, and the results, as a whole, are given by Col. Mendell in the Municipal Report for 1875-6 as 1,116 million gallons. By adding this to the amount reported by Mr. Scowden, the total run-off for the season 1874-5 becomes 13,464 million gallons.

A copy of these tables of run-off and rainfall, reported by Mr. Scowden, follows:

WATER SUPPLIES.

TABLE II.—DAILY DISCHARGE OF CALAVERAS CREEK FROM DECEMBER 2, 1874, TO MARCH 31, 1875, INCLUSIVE.

Date—	Discharge.	
December 2, 1874	23,470,000	gallons
December 3, 1874	23,470,000	"
December 4, 1874	23,470,000	"
December 5, 1874	23,470,000	"
December 6, 1874	23,470,000	"
December 7, 1874	23,470,000	"
December 8, 1874	23,470,000	"
December 9, 1874	23,470,000	"
December 10, 1874	23,470,000	"
December 11, 1874	23,470,000	"
December 12, 1874	23,470,000	"
December 13, 1874	23,470,000	"
December 14, 1874	23,470,000	"
December 15, 1874	23,470,000	"
December 16, 1874	23,470,000	"
December 17, 1874	23,470,000	"
December 18, 1874	23,470,000	"
December 19, 1874	23,470,000	"
December 20, 1874	23,470,000	"
December 21, 1874	23,470,000	"
December 22, 1874	23,470,000	"
December 23, 1874	23,470,000	"
December 24, 1874	23,470,000	"
December 25, 1874	23,470,000	"
December 26, 1874	23,470,000	"
December 27, 1874	23,470,000	"
December 28, 1874	23,470,000	"
December 29, 1874	23,470,000	"
December 30, 1874	23,470,000	"
December 31, 1874	23,470,000	"
January 1, 1875	23,470,000	"
January 2, 1875	23,470,000	"
January 3, 1875	23,470,000	"
January 4, 1875	23,470,000	"
January 5, 1875	23,470,000	"
January 6, 1875	23,470,000	"
January 7, 1875	23,470,000	"
January 8, 1875	23,470,000	"
January 9, 1875	23,470,000	"
January 10, 1875	19,461,000	"
January 11, 1875	19,461,000	"
January 12, 1875	19,461,000	"
January 13, 1875	19,461,000	"
January 14, 1875	23,470,000	"
January 15, 1875	605,247,000	"
January 16, 1875	239,421,000	"
January 17, 1875	385,744,000	"
January 18, 1875	169,078,000	"
January 19, 1875	3,360,968,000	
January 20, 1875	994,580,000	"
January 21, 1875	316,215,000	"
January 22, 1875	358,293,000	"
January 23, 1875	358,293,000	"
January 24, 1875	545,865,000	"
January 25, 1875	431,542,000	"
January 26, 1875	264,988,000	"
January 27, 1875	245,013,000	"
January 28, 1875	245,013,000	"
January 29, 1875	238,768,000	"
January 30, 1875	239,421,000	"
January 31, 1875	171,517,000	"
February 1, 1875	113,993,000	gallons
February 2, 1875	113,993,000	"
February 3, 1875	113,993,000	"
February 4, 1875	83,954,000	"
February 5, 1875	69,754,000	"
February 6, 1875	50,255,000	"
February 7, 1875	50,255,000	"
February 8, 1875	41,842,000	"
February 9, 1875	41,842,000	"
February 10, 1875	41,842,000	"
February 11, 1875	41,842,000	"
February 12, 1875	41,842,000	"
February 13, 1875	41,842,000	"
February 14, 1875	41,842,000	"
February 15, 1875	32,144,000	"
February 16, 1875	32,144,000	"
February 17, 1875	32,144,000	"
February 18, 1875	32,144,000	"
February 19, 1875	32,144,000	"
February 20, 1875	32,144,000	"
February 21, 1875	32,144,000	"
February 22, 1875	32,144,000	"
February 23, 1875	32,144,000	"
February 24, 1875	32,144,000	"
February 25, 1875	29,668,000	"
February 26, 1875	29,668,000	"
February 27, 1875	29,668,000	"
February 28, 1875	29,668,000	
March 1, 1875	29,668,000	"
March 2, 1875	29,668,000	"
March 3, 1875	29,668,000	"
March 4, 1875	29,668,000	"
March 5, 1875	29,668,000	"
March 6, 1875	29,668,000	"
March 7, 1875	29,668,000	"
March 8, 1875	29,668,000	"
March 9, 1875	29,668,000	"
March 10, 1875	29,668,000	"
March 11, 1875	29,668,000	"
March 12, 1875	29,668,000	"
March 13, 1875	29,668,000	"
March 14, 1875	29,668,000	"
March 15, 1875	29,668,000	"
March 16, 1875	26,336,000	"
March 17, 1875	26,336,000	"
March 18, 1875	26,336,000	"
March 19, 1875	26,336,000	"
March 20, 1875	23,470,000	"
March 21, 1875	23,470,000	"
March 22, 1875	23,470,000	"
March 23, 1875	23,470,000	"
March 24, 1875	23,470,000	"
March 25, 1875	23,470,000	"
March 26, 1875	23,470,000	"
March 27, 1875	23,470,000	"
March 28, 1875	23,470,000	"
March 29, 1875	23,470,000	"
March 30, 1875	23,470,000	"
March 31, 1875	23,470,000	"

Total discharge in 120 days, 12,347,817,000 gallons.

Details of the remainder of the report were lost in the fire of 1906, and are therefore not available.

The general results of the second set of measurements, covering the seasons 1875-6 and 1876-7 are to be found in the report of Col. George H. Mendell on the water supply of San Francisco, published in the San Francisco Municipal Report for 1876-77.

Colonel Mendell's rain records cover but a few months of the whole year and have little value. He reports the total run-off of Calaveras Creek at the damsite as follows:

	Run-off.
For season 1875-76	58,230
For season 1876-77	2,800

Unfortunately, the details of these measurements are not recorded by Colonel Mendell, so they cannot be recomputed, nor can they be analyzed in detail. It appears that the run-off for the season 1875-6 is 84.06 per cent of the area rainfall for that season, as determined by this report. This appears excessive, though it is probably due to abnormal rainfall distribution and intensity.

The run-off for the season 1876-7, as given by Col. Mendell, appears to be 14.63 per cent of the area rainfall for that season—11.19.

Measurement of Calaveras Creek Taken by Spring Valley Water Company as Far Back as 1888.

Subsequent to the measurements recorded in Col. Mendell's report three sets of measurements have been taken by the Spring Valley Water Company:

1st. Those taken by George Hadsell from 1888 to 1904, which will be referred to hereafter as the Hadsell Measurements;

2nd. Those taken by Mr. M. Gabrielsen, under the direction of Cyril Williams, Jr., from 1904 to 1908, and hereafter referred to as the Williams Measurements; and

3rd. Those at present being taken by Mr. P. F. Jones, Assistant Engineer, in charge of the construction work at Calaveras Dam, which will hereafter be referred to as the Jones Measurements.

The Hadsell Measurements.

The Hadsell measurements were taken over a course 70 feet long. The course was fairly straight and of even cross-section. The bottom and sides were gravelly, with a scattering of moderate-sized boulders, such as is found in any stretch of a creek in a mountainous country. Altogether, it was a fairly good course for a mountain stream. Survey of an average cross-section of the course was made in 1889 and again in 1902. During very low water periods a bedrock fall was used, which is located at the upper end of the gorge just below the dam. When the flow was sufficiently low to be forced through the fall with a reasonable depth, the depth of water over bedrock was recorded and the quantity computed by the use of the ordinary Francis weir formula.

The time taken by a float to travel the length of the seventy-foot course in the thread of maximum surface velocity was recorded, as well as the depth of water in the section. These observations were made daily.

Although the records were taken from 1888 to 1904, only that portion from 1898 to 1904 are now available, the remainder having probably been destroyed in the fire of 1906. The records left by Mr. Hadsell indicate that he was a very careful, painstaking man, as well as a very keen observer.

Discharge of the Calaveras Creek, during the period of the Hadsell records, has been very carefully worked up from the original records made by Mr. Hadsell. It is not claimed that these results are within the degree of precision that now obtains in hydrographic work, though they are consistent and, I believe, are very close to the true stream flow over that period.

Hadsell Measurements Very Conscientiously Taken.

In nearly all of Mr. Hadsell's semi-monthly reports he commented on the meteorological phenomena in the Calaveras region. He ascribed reasons, known to all persons familiar with hydrologic work, for apparent discrepancies in velocity measurements for similar depths of water, such as those due to the rising and receding flows, and to direction of wind currents. He noted intensities of rainfall, at the reservoir site, where a gage was maintained, as well as the comparative intensities of stream discharges there. Photographic reproductions of

Report of Flow of Water in Calaveras Creek.

from Feb 1st ~~18~~ 1902, to the 15th inclusive.

DATE.		Depth in Inches	Width in Feet	Velocity for 70 Feet.	Rain Fall in Inches.	REMARKS.
Feb	1st	16	2	38 sec		on the 10th the Creek Commenced
"	2nd	"	"	"	"	to Rase without rain enough to
"	3rd	"	"	"	"	here to cause it. Showing that
"	4th	18	"	30		more rain had fallen on the
"	5th	"	"	"	"	head waters of the Arorahonda
"	6th	19	"	~~28~~ 28		and the Alameda. I can not
"	7th	"	"	"		gage you the width of the creek
"	8th	20	"	26	"	wider than 10 ft. Mr Geo.
"	9th	"	—	"		Schussler took the aproxam-
"	10th	24	6	24	"	ate width of the Stream at
"	11th	26	8.	21	"	the Dam Site for high water
"	12th	28	10	20	"	and so told me to report
"	13th	30		19	"	Depth & velocity (only) in
"	14th	34		18	"	Winter as I have no means
"	15th	36		17	"	of getting the width in Winter. I
						Sopose it is on file in his office,

Respectfully Submitted
Geo Hadsell

P. O. Box 91
Milpitas
Cal

Plate-B12

Mr. Hadsell's remarks show that rain often fell in other parts of the Calaveras Watershed when none fell at Calaveras.

Report of Flow of Water in Calaveras Creek.

from Feb 15th ~~18~~ 1902, to the 28th inclusive

DATE.		Depth in Inches	Width in Feet	Velocity for 70 Feet.	Rain Fall in Inches.	REMARKS.
Feb	16th	30		19 sec		You will notice in my
"	17th	"		" "		Report, that the velocity is
"	18th	28		20 "		not the Same always, at
"	19th	26		21 "		the Same Depth, because
"	20th	25		22 "		when the Creek is raising
"	21st	24		23 "		the velocity is greater at
"	22d	90		10 "		the Same Depth than it
"	23d	72		11 "		is at the Same Depth.
"	24th	80		10 "		when falling,
"	25th	74		12 "		
"	26th	70		" "		velocity, 70 ft. 8 Seconds
"	27th	80 at 9 a.m. 90 and Raising at 1 P.M. 100 inches and falling.				
"	28th	60		12 "		it came up 20 inches with

in two Hours. very little Rain here but heavy Rain on the head waters of the Arroyo Hondo & Isabell.

Respectfully Submited
Geo Hadsell.

Plate-B 13

Mr. Hadsell's observations show that he was keenly alive to his work.

Report of Flow of Water in Calaveras Creek.

from March 15th 1899, to the 31st inclusive.

DATE.	Depth in Inches	Width in Feet	Velocity for 70 Feet.	Rain Fall in Inches.	REMARKS.
1899					
March 16th	72		11 Sec	.87 1/00	
" 17th	64		12 "		Rain fall for Season
" 18th	60		13 "		to Date 20.08
" 19th	"		" "		85 1/00 to the Same date
" 20th	74		10 "		last Season 10.97
" 21st	68		12 "		
" 22nd	96		09 "	1.61	Rain fall for this
" 23rd	100		08 "	1.91	March 9.83
" 24th	90		10 "	.77 1/00	for last March .91 1/00
" 25th	68		11 "		
" 26th	64		12 "		
" 27th	60		13 "		
" 28th	"		" "	.40	
" 29th	64		13 "		
" 30th	60		" "		
" 31st	54		14 "		

Respectfully Submitted

Geo Hadsell,

Plate-B 14

Mr. Hadsell appreciated the value of comparative hydrographic data.

Report of Flow of Water in Calaveras Creek.

from March 1st 1899, to the 15th inclusive.

DATE.		Depth in Inches	Width in Feet	Velocity for 70. Feet.	Rain Fall in Inches.	REMARKS.
1899					.35 00	
March	1st	10	7	35 Seconds		March 16th
"	2nd	"	"	"	.08	the Rain fall for
"	3rd	11	8	"		40 hours: Ending
"	4th	"	"	"	"	at 5 Oclock this a. m.
"	5th	"	"	"	"	has been 3.50
"	6th	"	"	"	"	70/00 of this fell since
"	7th	"	"	"	"	midnight: as will
"	8th	10	7	"	"	appear in my
"	9th	"	"	"	"	next Report,
"	10th	"	"	"	.19/00	Rain fall to date
"	11th	"	"	"		13.67
"	12th	9	"	34		last Season to the
"	13th	"	"	"	"	Same date 10.36
"	14th	10	"	"	" .50/00	
"	15th	42		18	" 2.30	

at 1 oclock P.m. (the 15th) the water in the creek
was 42 inches. velocity 18 seconds
at 5 oclock P. M. it was 84 inches. velo. 10 Sec.
Respectfully Submitted
Geo Hadsell.

Plate-B 15

Mr. Hadsell realized the effect of intensity of rainfall on the run-off.

Report of Flow of Water in Calaveras Creek.

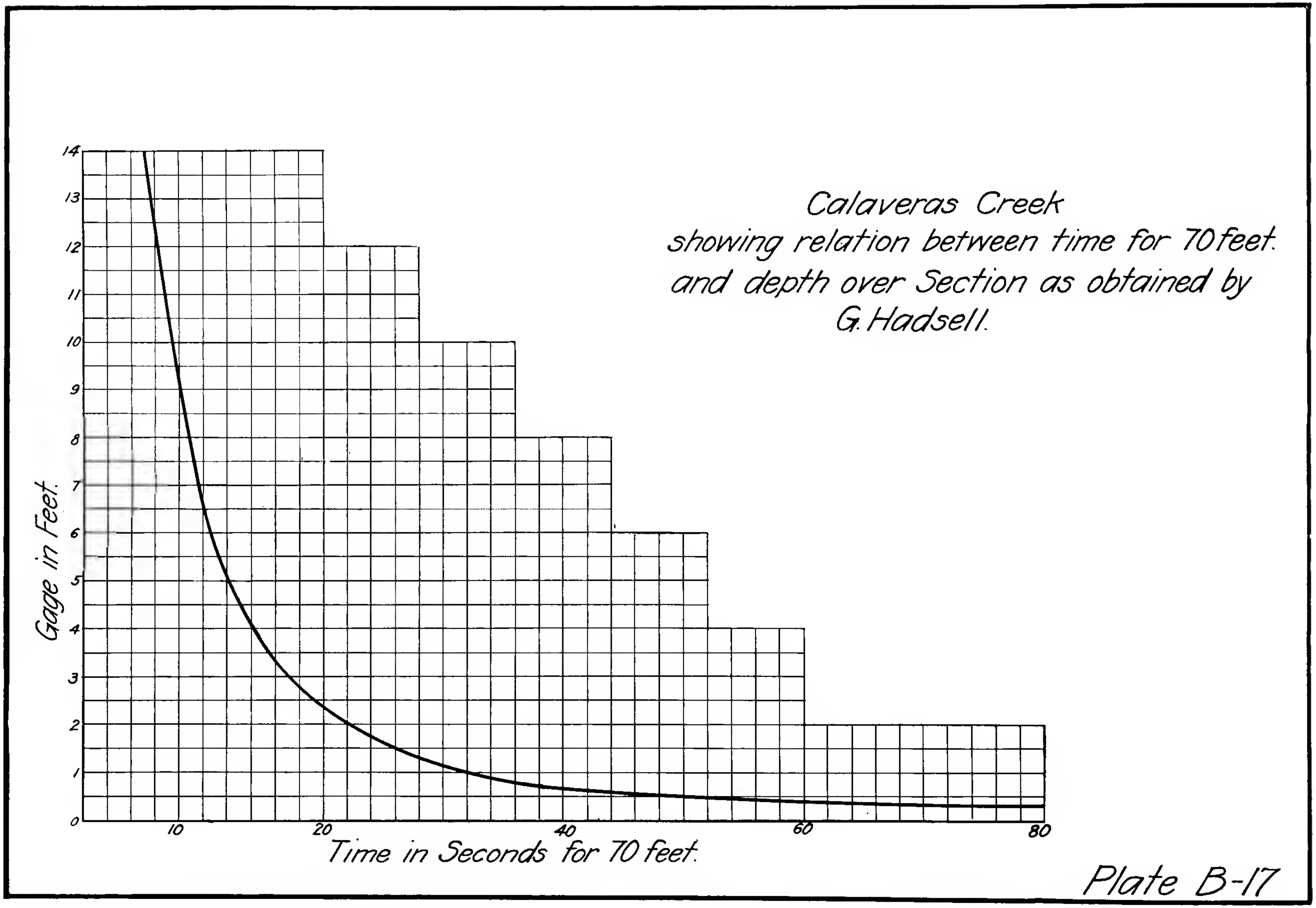
from May 1st 1901, to the 15th inclusive.

DATE.		Depth in Inches	Width in Feet	Velocity for 7.0.. Feet.	Rain Fall in Inches.	REMARKS.
May	1st	36		17 sec	.52	Rain fall to Date 29.46
"	2"	34		19 "		Same date last season 27.43
..	3rd	30		20 ..		I wonder what is the
..	4th	28		20 ..		Matter with your S.F.
..	5th	26		21 ..		weather sharp he must
..	6th	24		22 ..		keep his Rain gage in
..	7th	22		24 ..		his office or some
..	8th	20		25 ..		place under cover
..	9th	20		25 ..		it does not seem
..	10th	19		26 ..		~~that~~ there could be a
..	11th	1.9		26 ..		differance of 9 inches
..	12th	1.9		2.6 ..		betwine S.F. and here.
..	13th	18		28 ..		last season there was a
..	14th	1.8		2.8 ..		differance of 6.01 betwine
..	15th	1.8		28 ..		S.F. and here I know that
		.381		.75		My Record is correct.

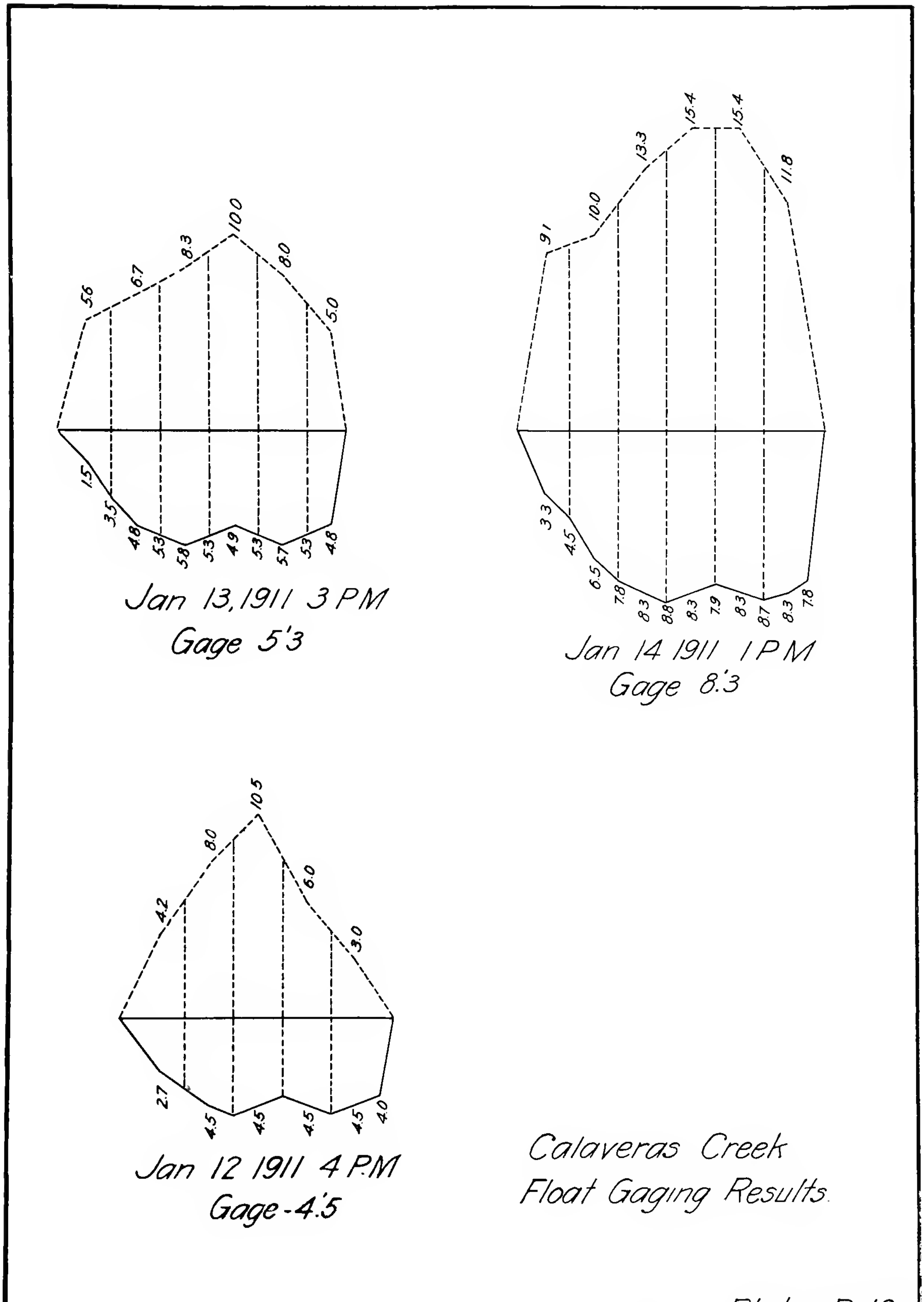
Respectfully Submitted
Geo Hadsell.

Plate-B 16

Such comments as these show that Mr. Hadsell was exceedingly conscientious.



THIS SHOWS GRAPHICALLY THE RAPID INCREASE IN VELOCITY WITH DEPTH.



A SERIES OF FLOAT MEASUREMENTS AT CALAVERAS WERE USED TO DETERMINE THE RELATION BETWEEN SURFACE AND MEAN STREAM VELOCITY.

some of his reports, which show this character, are given in Plates B-12, B-13, B-14, B-15 and B-16.

His records are so replete with notes of value, as to inspire the utmost confidence in the results reported by him, as well as to afford to one unfamiliar with the Calaveras drainage area a fairly complete knowledge of the habits of its streams.

Attention is called to the reports ending March 15 and March 31 (Plates B 14 and B 15), where note has been made of greater flow at 5 p. m. on the 15th of March, than is reported for the morning of either the 15th or the 16th of March. In the computation of flow from Mr. Hadsell's records, no account has been taken of any departures from the depths observed on the morning of the day for which the observation was made. The depths used throughout have been recorded in the column marked "Depth in inches." It has been assumed, in this connection, that whatever fluctuations may have occurred in the computed discharges above and below the actual flow, have been compensating, and it is believed that the computed discharges for each season represent closely the actual discharge for that season.

The method of computing the stream flow at Calaveras from the data recorded by Mr. Hadsell was as follows:

Method of Computing Flow from Hadsell Measurements.

The velocities (surface, in the thread of the stream or the time in seconds required to travel 70 feet in length) fluctuated for the same depths, for reasons already stated, as noted by Mr. Hadsell in his reports. The fluctuations, however, varied within practically the same limits from year to year for the period covered by these records (1898 to 1903), indicating that no changes of any consequence had occurred in the channel section. It was therefore assumed that the maximum surface velocity for the various depths was approximately a mean between the fluctuating velocities recorded in the reports.

The various lengths of time required in seconds to travel 70 feet, as recorded in the reports, were plotted (Plate B-17) as ordinates, and the corresponding depths were plotted as abscissae. A curve was drawn approximately through the means of the points, and was assumed to represent the maximum surface velocity for the corresponding depth, and Mr. Hadsell's records of velocity were corrected accordingly. Thus, in the computations of flow, from Mr. Hadsell's records, only the depth, as recorded by him was used.

Coefficients Are Determined from Actual Gagings.

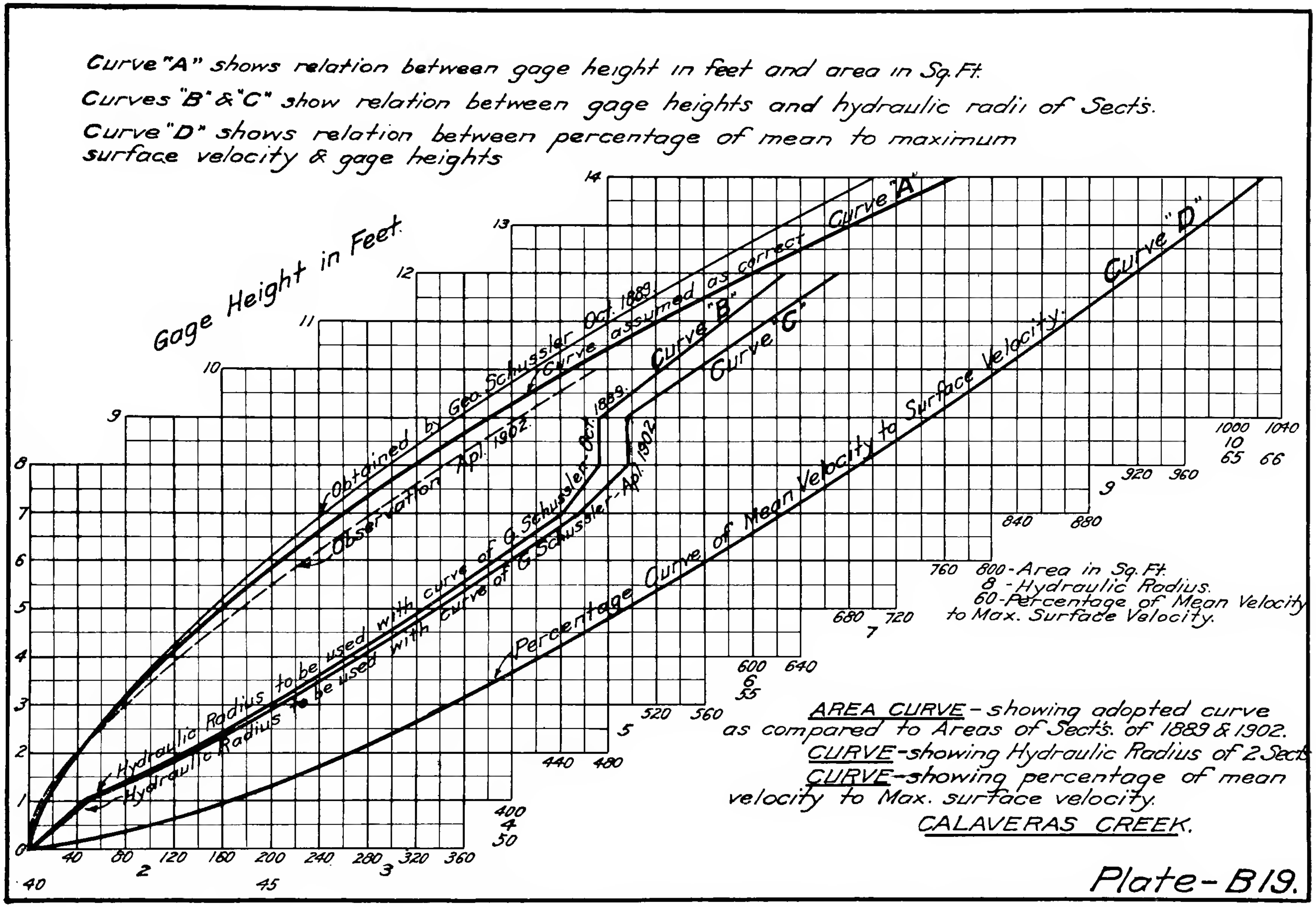
From the curve (Plate B-17), showing the time required for a float to travel 70 feet in the thread of the stream, the maximum surface velocity was obtained. In order to arrive at the proper percentage to apply to the maximum surface velocity, to obtain the mean stream velocity, consideration was given to the hydraulic elements of the channel. There were also available a series of float gagings, made in the Calaveras Creek by Mr. P. F. Jones during some of the flood discharges in 1911 and 1912 in practically the same location and with practically similar conditions of stream bed as obtained in the 70-foot section used by Mr. Hadsell. The depth of water in the channel during these experiments varied from 3.4 feet to 13.2 feet on the gage.

In conducting these experiments for the purpose of establishing a rating curve, Mr. Jones surveyed three sections in the course over which his measurements were taken. In this channel he took current meter measurements up to a gage height of 6½ feet. Above this height the velocity and interference from drift wood were so great as to render the work with a current meter impracticable. For greater depths than 6½ feet, float gagings were made by obtaining the velocity in longitudinal sections, approximately 10 feet apart. To check the accuracy of the flood gagings, similar experiments to that above stated were made at shallower depths than 6½ feet.

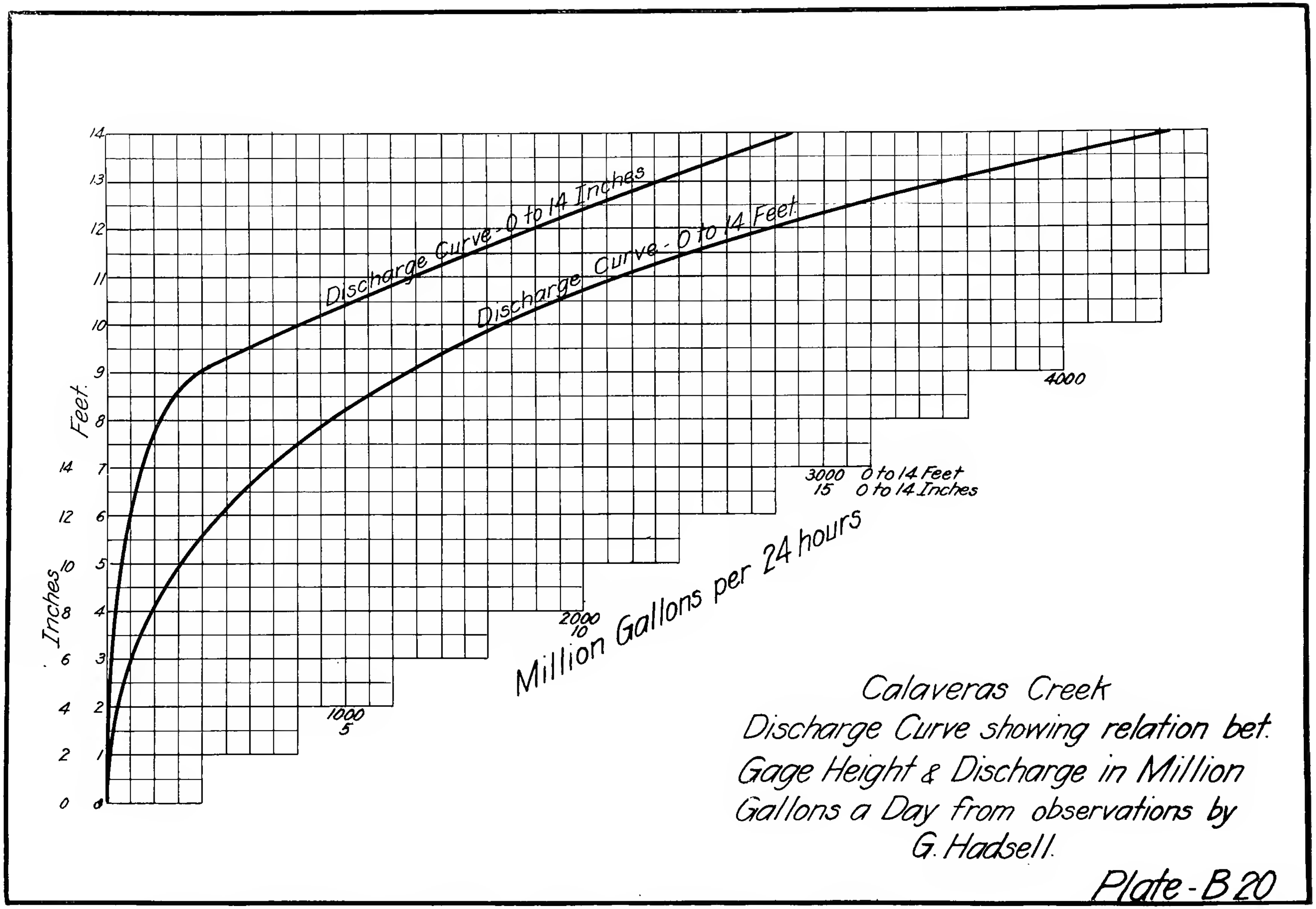
Diagrams showing the results of the float experiments are shown in Plate B-18.

The results obtained from the Jones gagings were found in close agreement with the results of the experiments of many eminent hydraulic engineers upon the flow of water in channels of this kind.

A curve was therefore made in accordance with these various experiments which shows, for various gage heights, the probable relation existing between the mean stream velocity and the



THE CO-EFFICIENTS APPLIED TO THE SURFACE MEASUREMENTS OF CALAVERAS CREEK BASED UPON ACTUAL EXPERIMENTS.



STREAM FLOW FROM THE HADSELL RECORDS WAS COMPILED BY MEANS OF THIS DISCHARGE CURVE.

Apr. 5th 82

Mr. Geo. Hadsell

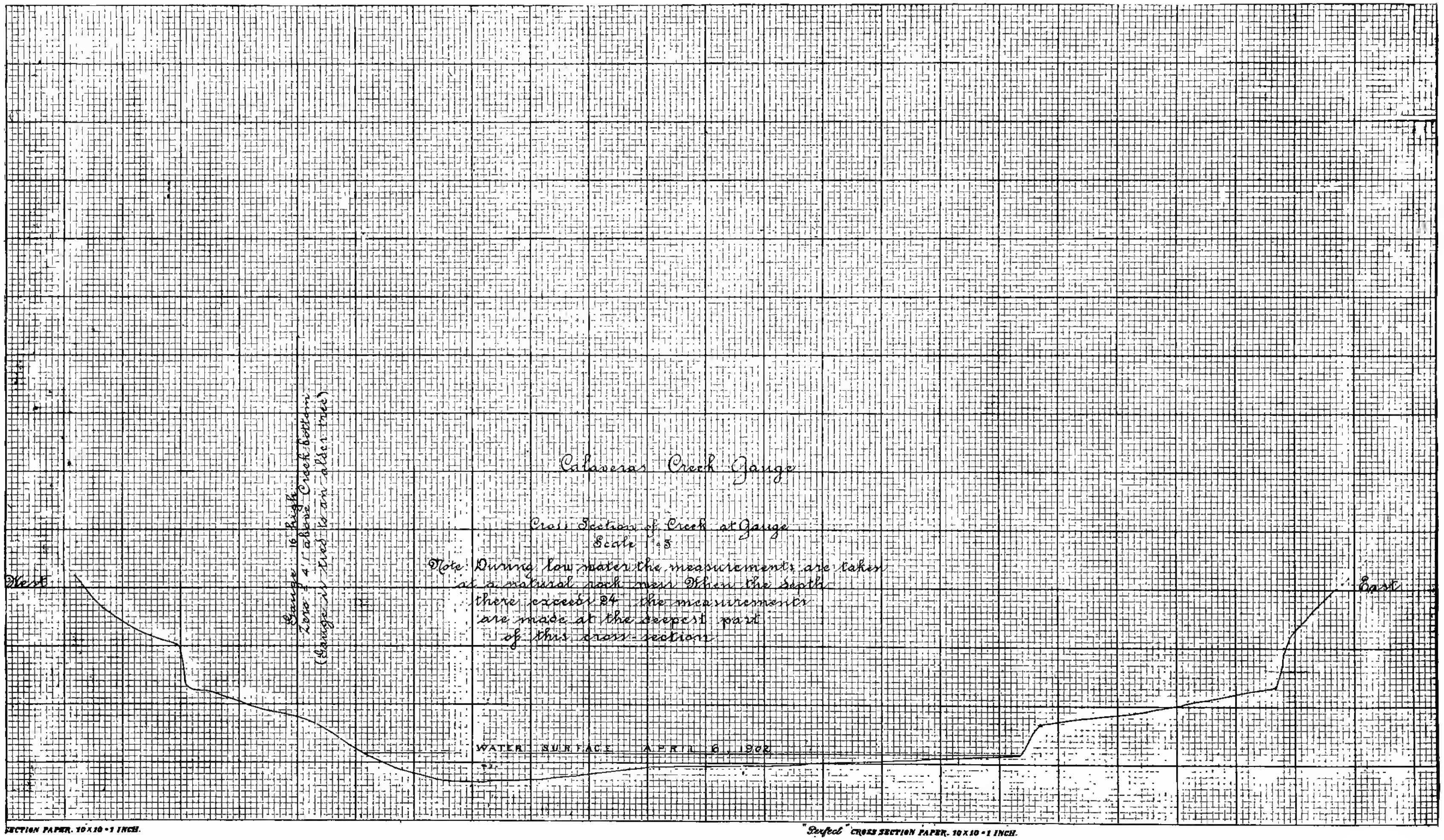
Dear Sir:—

The bearer Mr. Cheminant
one of our surveyors—is going
to get a cross section of
Calaveras Creek where you
take your measurements from
show him the place and assist
him all you can

Yours Respy.
M. M. Garoutte
Chief Clerk Eng. Dept.
Spring Valley Water Works—

Plate-B 21

THESE INSTRUCTIONS SHOW THAT SURVEY OF CROSS-SECTION WAS MADE WHERE MEASUREMENTS OF FLOW IN CALAVERAS CREEK WERE TAKEN BY MR. HADSELL.



CROSS SECTIONS OF CALAVERAS MADE IN APRIL 1902, AT POINT WHERE HADSELL MEASUREMENTS WERE TAKEN.

Plate B-22

maximum surface velocity, determined from curve, Plate B-17, and shown on Plate B-19.

The increase in the hydraulic radius with the increase in gage height was also used as a guide in developing the curve showing the relation between maximum surface velocity and probable mean stream velocity.

The product of the mean stream velocity, thus found for each gage height, applied to the area of the channel at that height, gave the discharge. These discharges were plotted for each foot on the gage, as abscissae, while the gage heights were plotted as ordinates and the points were connected by a curve, which was adopted as the discharge curve for Calaveras Creek to be applied to the Hadsell measurments. This is shown on Plate B-20.

Cross-Sections Determined by Actual Surveys.

In October, 1889, a survey of the section used by Mr. Hadsell, and computations of area for various depths of the same, were made by Mr. George Schussler (see Plate B-20). This section was used by Mr. Hadsell throughout the entire period covered by his records. During the time intervening between October, 1889, when Mr. George Schussler's section was surveyed, and the time when the records of Mr. Hadsell, now available, began in 1898, several wet winters occurred, notably, 1889-90, 1892-3, 1894-5, and 1896-7, so that considerable of the change in section, from that surveyed by Mr. George Schussler in 1889, and that surveyed by Mr. L. B. Cheminant in April, 1902, probably occurred during the seasons named.

Mr. Cheminant was instructed to survey the section where the Hadsell measurements were taken as will be seen from the letter to Mr. Hadsell (for which refer to photographic copy, Plate B-21) and that he surveyed the section at that point will be seen from the memorandum noted on the map of the survey, made by Mr. Cheminant (for photographic copy of which see Plate B-22). Mr. Cheminant made both the survey and the map of the same.

The following table shows the areas at different elevations of the section surveyed by Mr. George Schussler in 1889, and of the survey by Mr. Cheminant, in 1902:

Depth in feet.	Areas, George Schussler, Section Square feet.	Areas, L. B. Cheminant, Section Square feet.
1	14	12
2	43	38
3	76	77
4	113	121
5	153	170
6	197	223
7	245	282
8	297	341
9	357	403
10	419	468
11	484	537
12	551	...
13	623	...
14	700	...

In making the computations from the Hadsell records, a curve (Curve A on Plate B-20) was adopted which, it is believed, closely represents the actual cross-sectional area curve during the period covered by these gagings, viz.: from 1898 to 1903.

Results from Computing the Hadsell Measurements.

The following table shows the computed discharges of Calaveras Creek during the period of the Hadsell records, at one foot intervals, from one foot to fourteen feet on gage:

Gage Height. Feet.	Discharge. Million Gallons Daily.
1	9.0
2	43.0
3	109.0
4	198.0
5	315.0
6	477.0
7	670.0
8	930.0
9	1,274.0
10	1,685.0
11	2,147.0
12	2,757.0
13	3,574.0
14	4,511.0

The following summary shows the estimated flow, by months, in million gallons, for the seasons of 1898-99 to 1902-03, based on Mr. Hadsell's measurements:

	SEASONS:				
	1898-99	1899-00	1900-01	1901-02	1902-03
	M. G.	M. G.	M. G.	M. G.	M. G.
July	14	248	484	1,047	870
August	5	35	137	581	304
September	4	12	51	224	32
October	9	55	184	297	11
November	4	1,225	6,149	312	326
December	5	3,213	638	842	542
January	2,641	5,414	5,074	612	2,321
February	317	497	4,348	4,851	3,143
March	7,763	1,706	1,353	3,286	4,256
April	1,861	954	591	838	2,973
May	592	709	1,089	430	387
June	505	492	434	71	306
Totals	13,720	14,560	20,532	13,391	15,471

From the rainfall records, discussed in Appendix "A", the estimated mean area rainfall, on the Calaveras drainage area, for the seasons covered by the Hadsell records, was as follows:

1889-99	23.35 inches
1899-00	27.57 "
1900-01	31.15 "
1901-02	25.44 "
1902-03	27.62 "

By reducing the run-off in million gallons for each of these seasons, to inches of rain for the Calaveras drainage area, we have the following:

	Run-off. Inches.	Rainfall. Per cent.
1898-99	8.04	34.26
1899-00	8.54	30.97
1900-01	12.00	38.52
1901-02	7.83	30.78
1902-03	9.06	32.8

The Williams Measurements.

Beginning in 1904, an effort was made to obtain more careful measurements of the flow of Calaveras Creek. Under the direction of Mr. Cyril Williams, Jr., a course 200 feet long, just above the Calaveras Damsite was chosen, in which to measure flood waters, and a concrete weir constructed to divert the stream during exploration work for the Calaveras Dam, was used to measure the low water flow.

Careful cross-section measurements of the 200-foot course were made every 25 feet. This course was straight, uniform of section, and as good as the 70-foot course, besides being longer, though because of interference with the flow at the lower end of the course, the latter portion of the Williams measurements was confined to the upper 100 feet of the 200-foot course, new channel cross-sections being taken every 20 feet of the 100 feet.

Change in Section Used by Williams Is Uncertain.

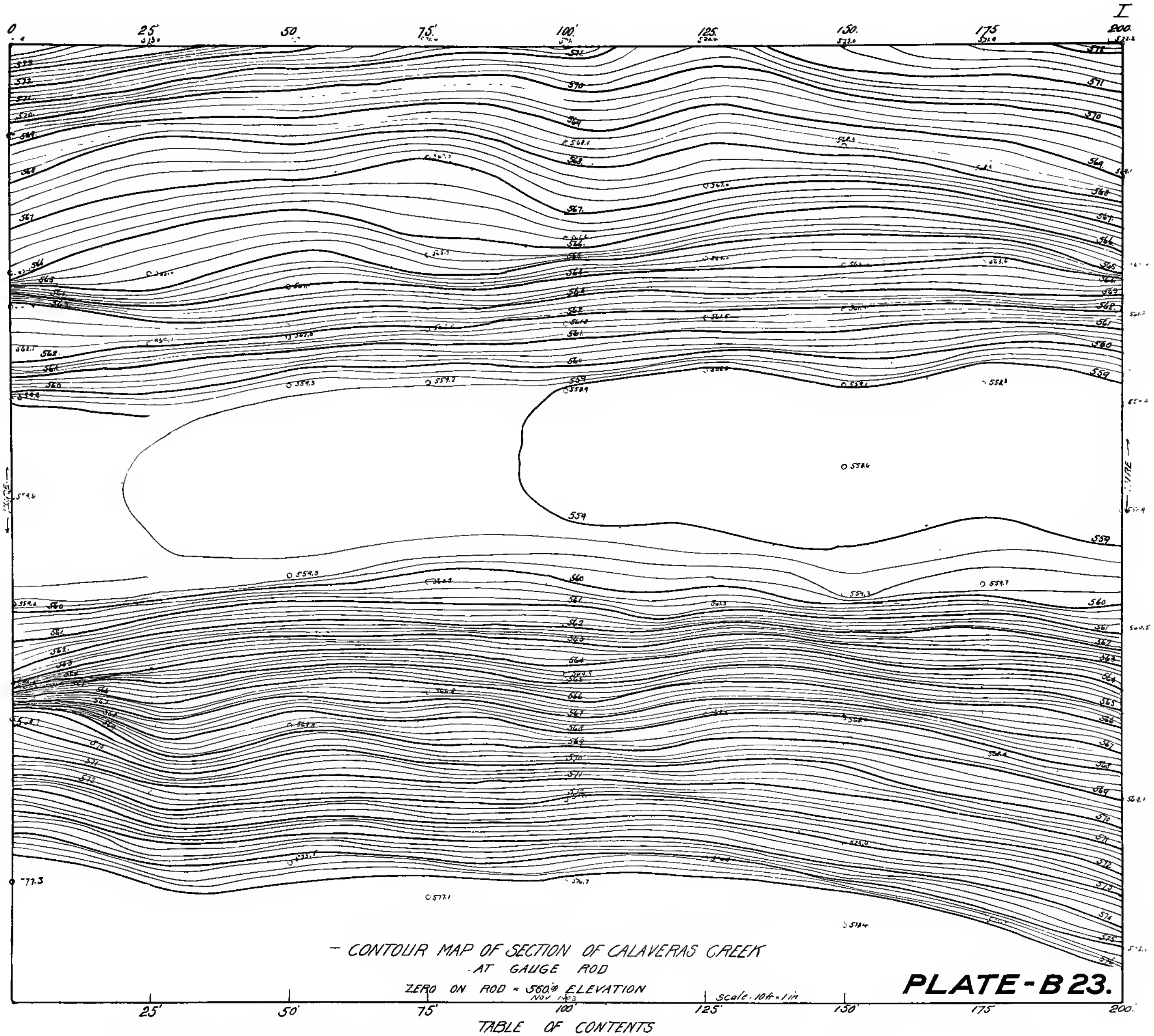
Recorded gagings indicate that measurements over the 100-foot course began in 1906, though the map of cross-sections made by Mr. Williams bears the date of 1908. Unfortunately, the field books containing the notes of this survey, which would relieve all doubt on this question, were destroyed in the 1906 fire. It is quite probable, of course, that the filing map of these sections was made a year after the surveys were made, and as the recorded gagings indicate this to be the case, I have accepted the change from the 200-foot course to the 100-foot course to have taken place as indicated in the gage records, and have disregarded the date given in the map made by Mr. Williams. As in the case of the 70-foot course, record was made of the time it took a float to travel over the course along the thread of maximum surface velocity. Instructions were issued not to use the concrete weir when the water was in excess of 18″ above its crest.

From the original records of the Williams measurements, re-computation of the flow of Calaveras Creek at Calaveras, during the seasons of 1904-5 to 1907-8, inclusive, were made. The flow for the first part of the season of 1903-4, viz.: from July 1st, 1903, to Feb. 7th, 1904, was computed from the records of Mr. Hadsell, taken at the 70-foot course and for the latter part from Feb. 8th, 1904, to June 30th, 1904, the flow was computed from the records over the 200-foot course.

From the results obtained in the distribution of the rainfall over the Calaveras drainage area, a computation was made of the probable rainfall over the area for each year of the 63-year period. In analyzing the run-off due to the rainfall for each year from 1898 to 1908 and from 1910 to 1912, it was found that the run-off computations made from the Williams data were for the most part so unreasonably high as compared with the rainfall that grave doubt arose as to reliability of the results. A recomputation of the data was therefore decided upon.

Williams Computations Are Erroneous.

It was found in checking the area of the nine cross-sections in the 200-foot course and of the six sections in the 100-foot course from the maps of these sections made by or under the direction of Mr. Williams, that the mean area of the nine and the six sections' area, respectively, at different gage heights was taken as representing the area of the 200-foot course and of the 100-foot course for corresponding gage heights. These areas were found to be in error as much as 25%, because in the original computation of areas for corresponding gage heights (the gage in both cases being at the upstream section), the areas in each of the nine and the six sections, respectively, of the



CAREFUL TOPOGRAPHICAL SURVEY OF THE GAGING STATION USED BY CYRIL WILLIAMS, JR., SHOWS THE GRADE IN CALAVERAS CREEK AT THIS POINT.

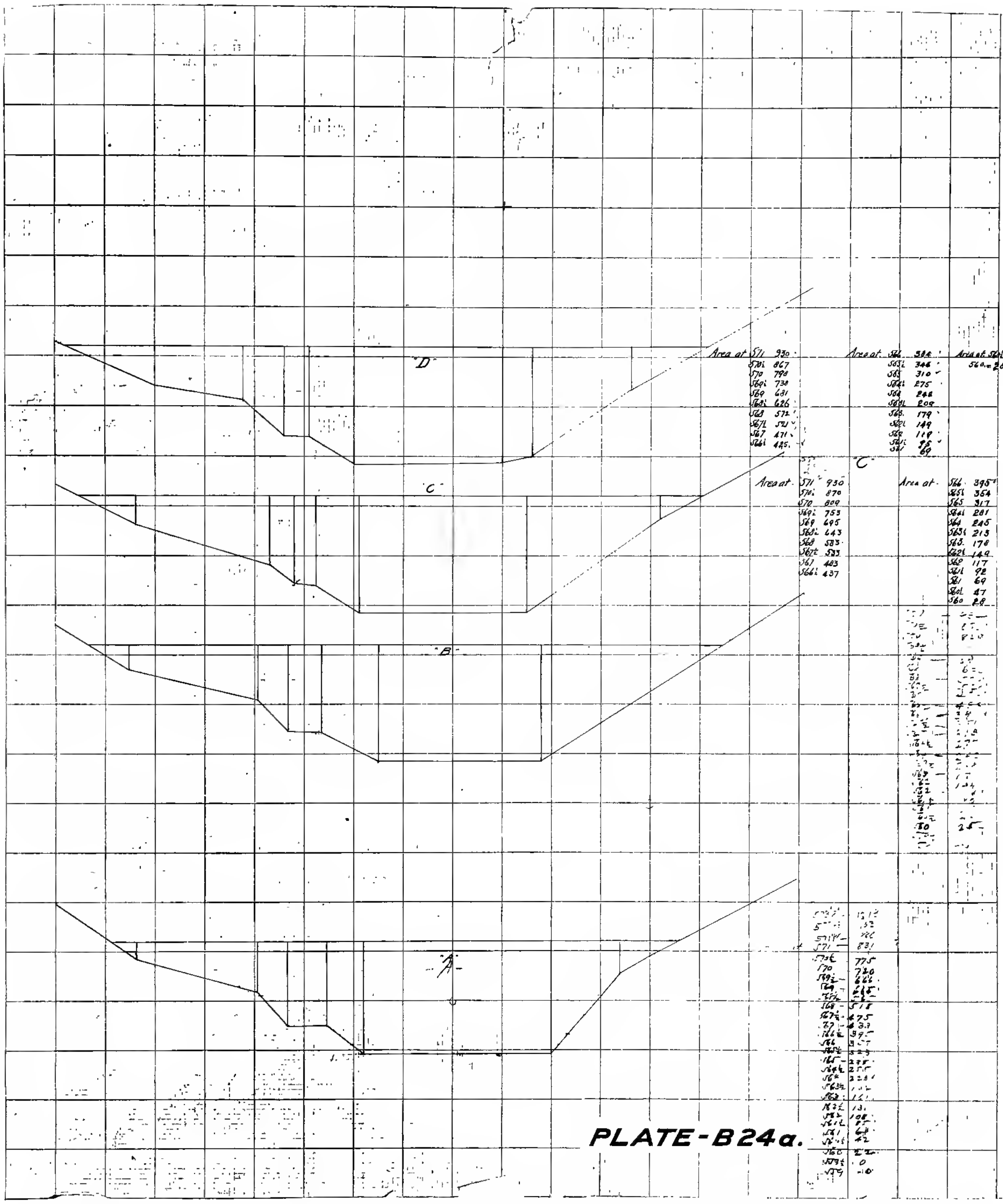
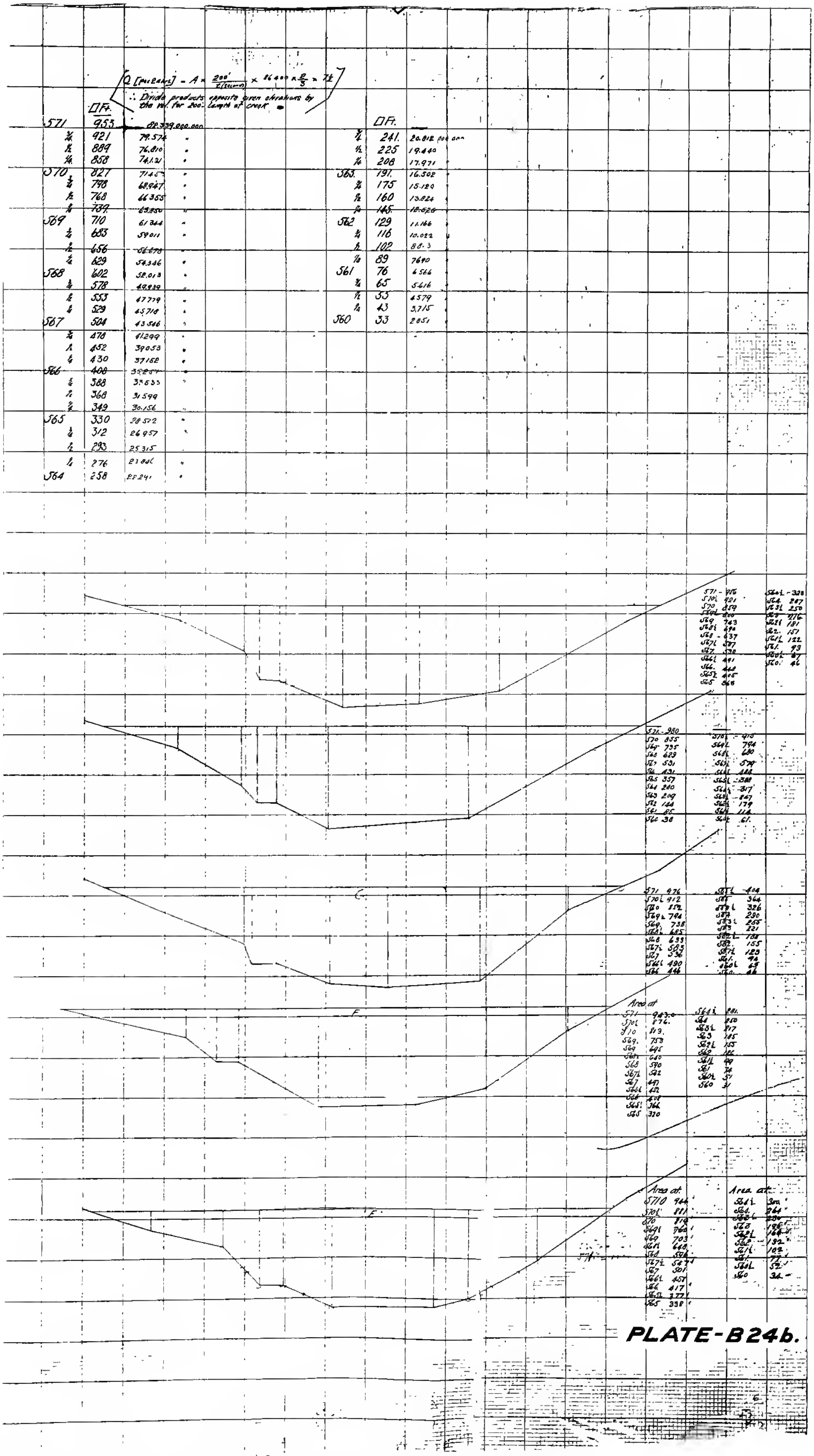
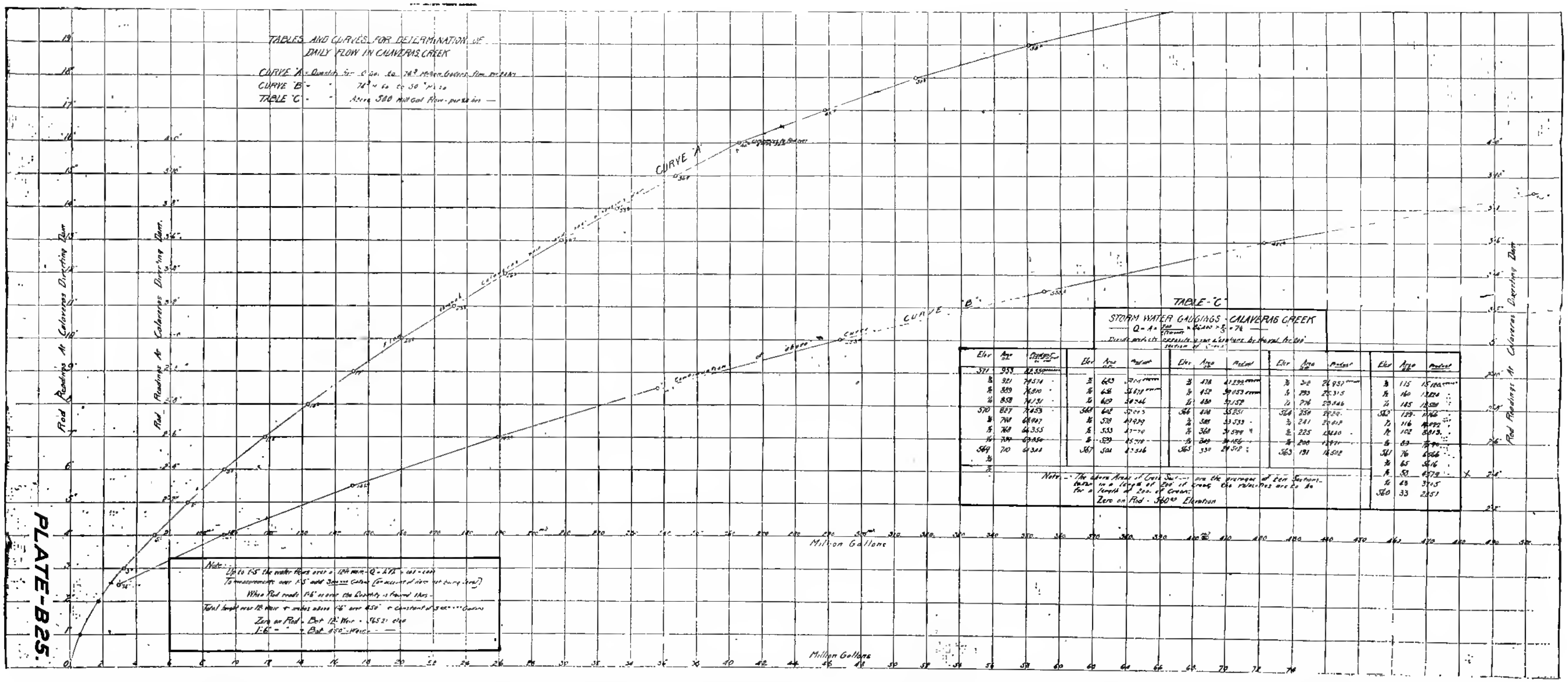


PLATE-B24a.

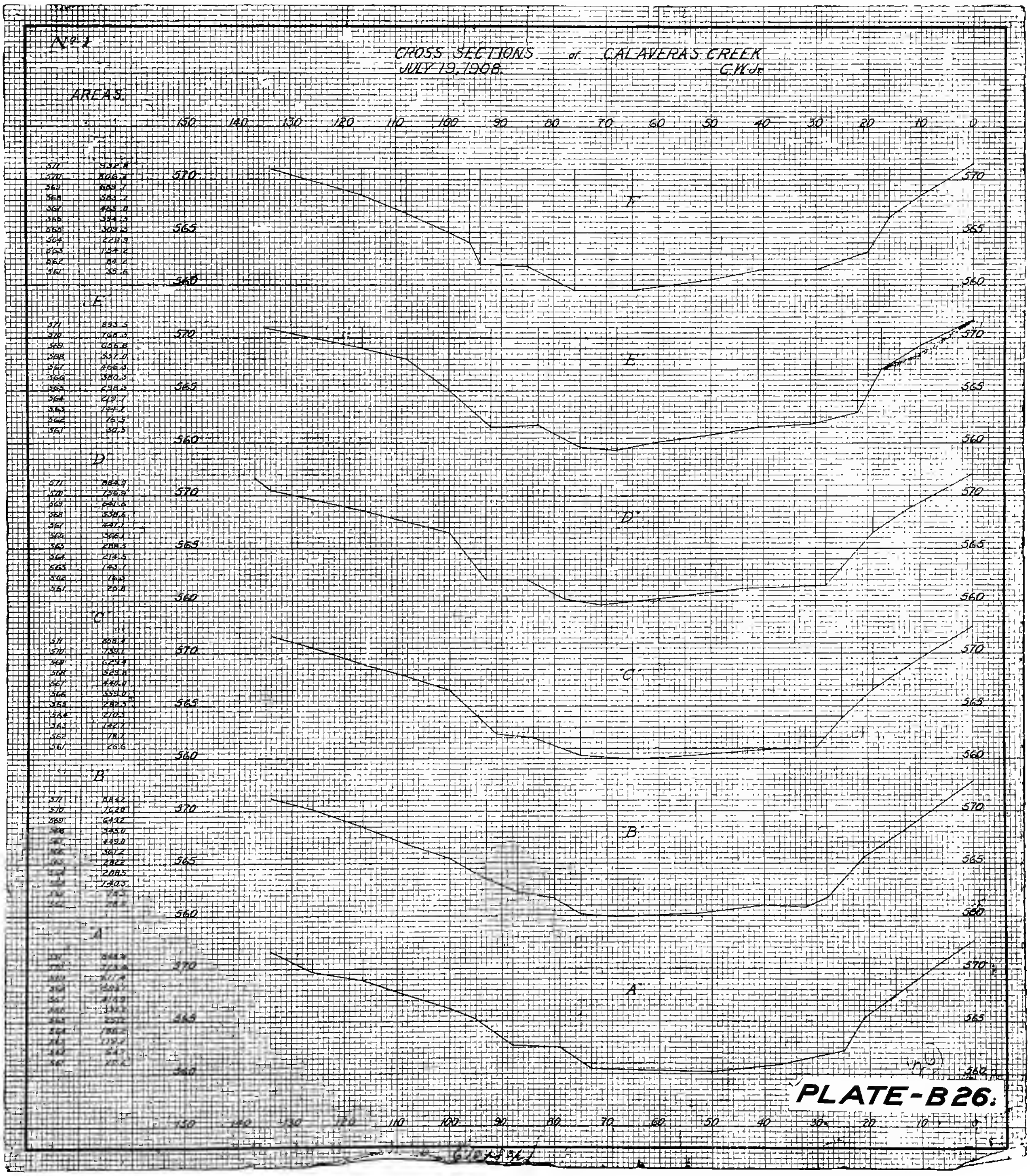
REPRODUCTION OF THE UPPER FOUR CROSS SECTIONAL AREAS USED BY WILLIAMS IN COMPUTING THE FLOW OF CALAVERAS CREEK OVER THE 200-FOOT COURSE. NO ALLOWANCE WAS MADE FOR SLOPE IN WATER SURFACE IN THIS 200 FEET.



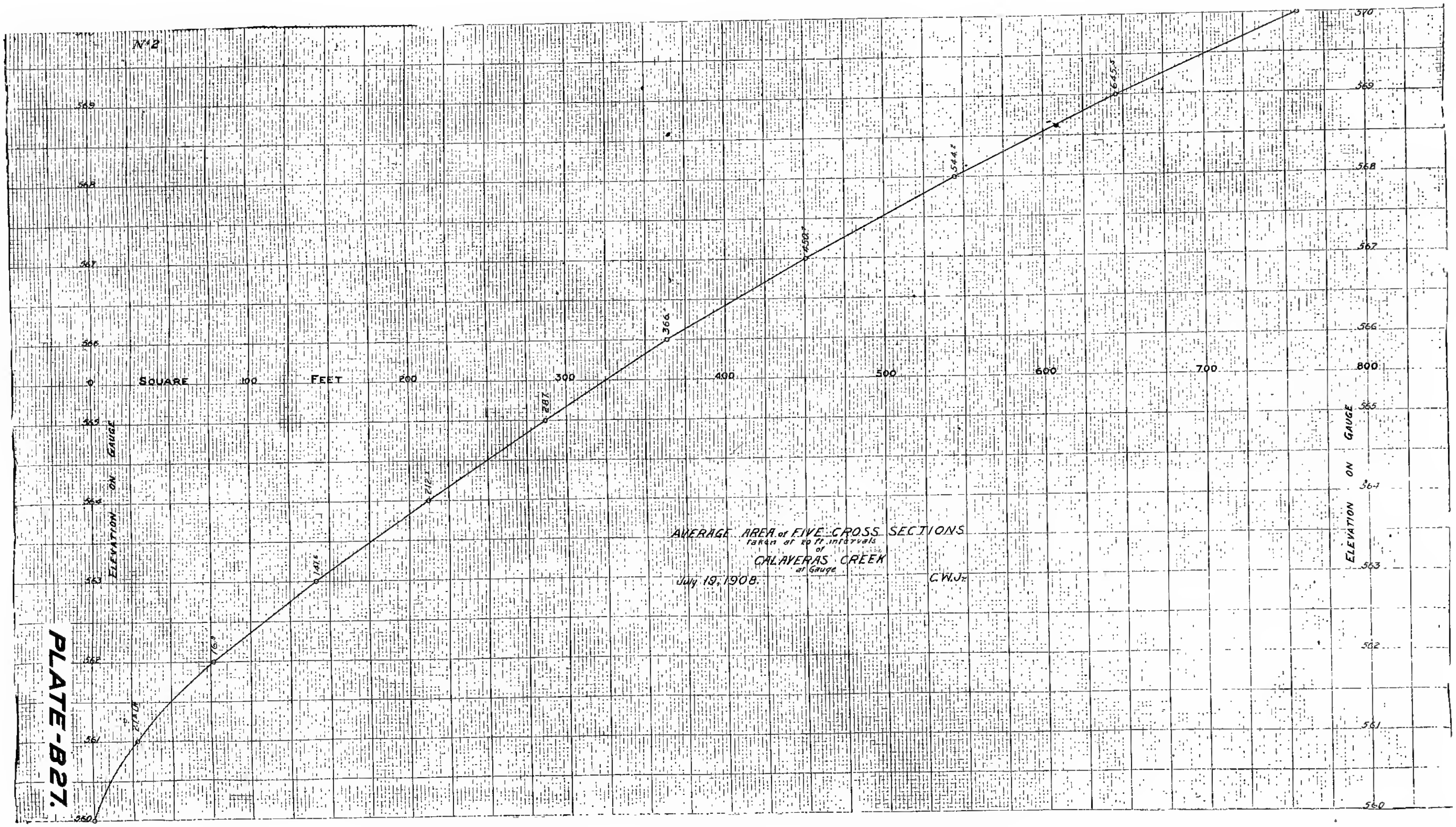
REPRODUCTION OF THE LOWER FIVE CROSS SECTIONAL AREAS USED BY WILLIAMS IN COMPUTING THE FLOW OF CALAVERAS CREEK OVER THE 200-FOOT COURSE. NO ALLOWANCE WAS MADE FOR SLOPE IN WATER SURFACE.



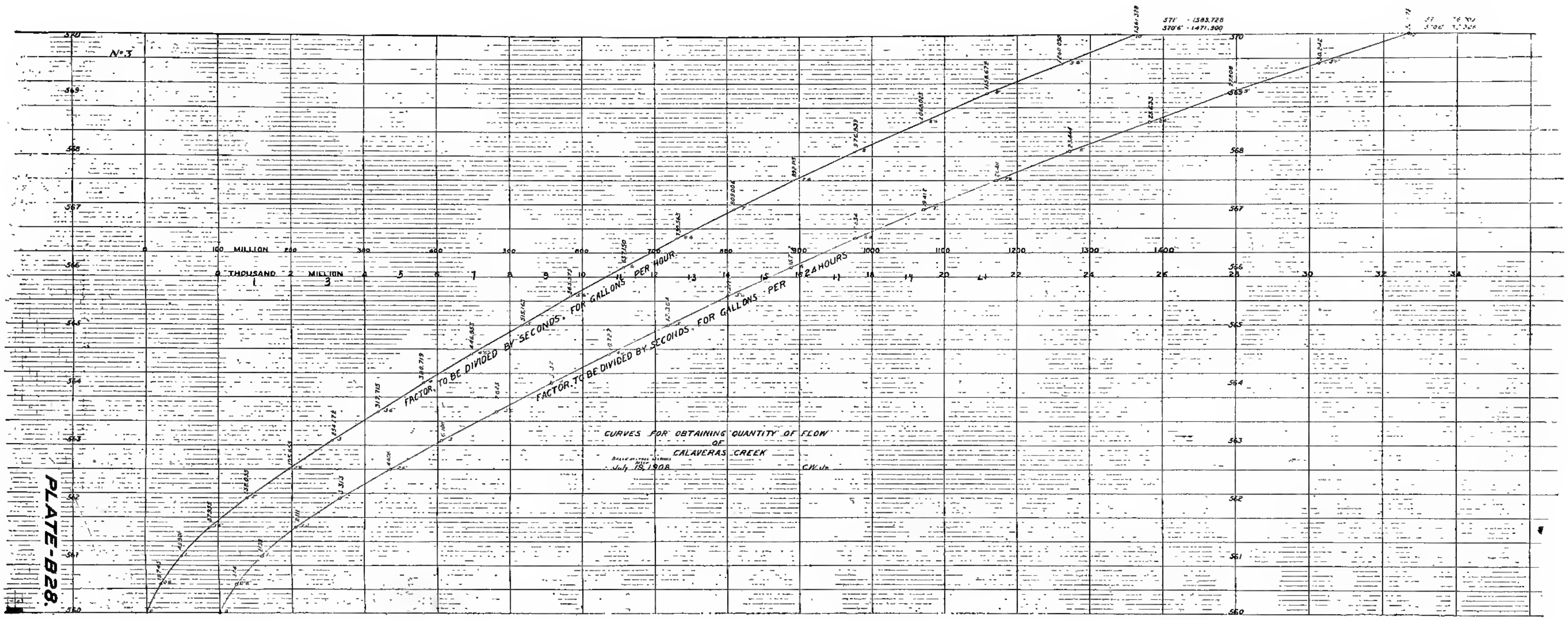
DISCHARGE CURVES FOR FLOW OF CALAVERA S CREEK (WILLIAMS), THE PART FOR HIGHER FLOWS BEING BASED ON CROSS-SECTIONAL AREAS WITHOUT DUE ALLOWANCE FOR SLOPE OF WATER SURFACE OVER MEASURED COURSE.



CROSS-SECTIONAL AREAS USED BY MR. WILLIAMS IN COMPUTING FLOW OF CALAVERAS CREEK OVER 100-FOOT COURSE. HERE AGAIN PROPER ALLOWANCE FOR SLOPE OF WATER SURFACE WAS NOT MADE.



THE AVERAGE AREA OF THE FIVE CROSS-SECTIONAL AREAS USED OVER THE 100-FOOT COURSE BY MR. WILLIAMS IN COMPUTING THE FLOW OF CALAVERAS CREEK. THIS IS IN ERROR.



FACTOR CURVE USED BY MR. WILLIAMS IN COMPUTING THE FLOW OF CALAVERAS CREEK BASED UPON CROSS-SECTIONAL AREAS, WITHOUT DUE ALLOWANCE FOR SLOPE IN WATER SURFACE.

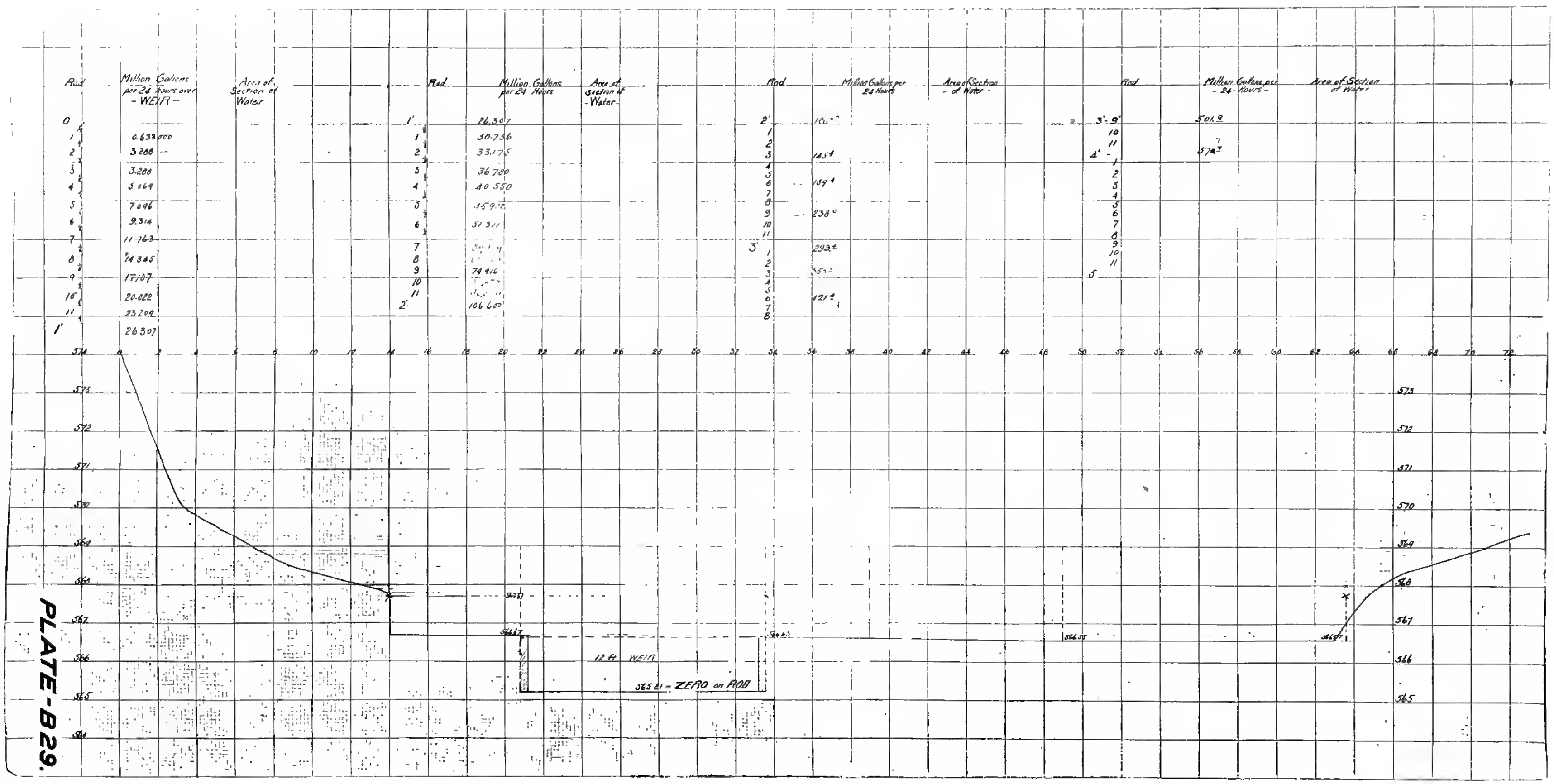
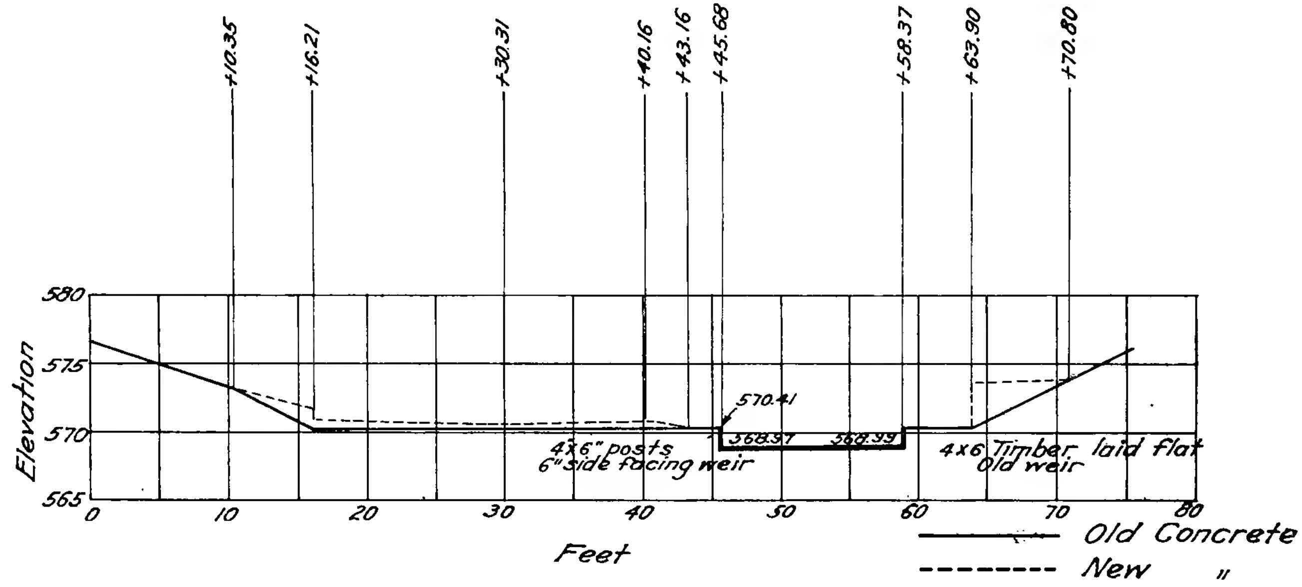


PLATE-B29.

LOW WATER FLOWS OF CALAVERAS CREEK IN WILLIAMS MEASUREMENTS WERE MEASURED THROUGH A CONCRETE WEIR, WHOSE EAST WING WAS NOT LEVEL, BUT WHICH WAS RECTIFIED FOR THE JONES MEASUREMENTS.



Calaveras Weir.

Plate-B30.

200-ft. and 100-ft. course was computed up to the level of the gage height.

Thus it will be seen that the water surface was considered level with the gage height throughout the 200-foot course, obviously a condition of no velocity and, no flow, and therefore clearly in error. From the elevations shown on the contour map of the 200-foot course (Plate B-23) it will be seen that this course has a drop of about one foot in 200 feet.

In the recomputations of the areas, allowance was made for the depths in each section, due to the slope of the channel.

There are inserted here photographic reproductions of the nine cross-sections in the 200-foot course, with table of computed areas of each section (Plate B 24); rating curve of 12-foot weir and table of flow through the 200-foot sections (Plate B-25); six cross-sections in the 100-foot course with table of areas for each section (Plate B-26); table of mean area of the five cross-sections (Plate B-27); factor curve for 100-foot section (Plate B 28); and cross-sections of 12-foot weir (Plate B 29).

These diagrams and maps were all made by or under the directon of Mr. Cyril Williams, Jr., and were used as a basis for the original computations of flow at Calaveras from February 8th, 1904, to June 30th, 1908, heretofore used by the Spring Valley Water Company.

It will be seen by referring to Plate B 25, showing rating curve for 12-foot weir and table of flow for the 200-foot section, that in the formula used in computing the flow through the 200-foot section the mean stream velocity was taken throughout at two-thirds (66 2-3%) of the maximum surface velocity, regardless of changes in the hydraulic elements of the channel due to variation in depth.

By computation it was found that the data shown on the factor curve (Plate B 28) was deduced by also using the same ratio (66 2-3 %) of the maximum surface velocity to obtain the mean stream velocity at all depths.

It will thus be seen—assuming the computations of flow from the data to be correct—that the discharge so computed must necessarily be very excessive because of the use of excessive areas and excessive velocities mentioned above.

Williams Measurements Recomputed.

A recomputation of the flow from the records taken from 1904-08 was made by Mr. G. G. Anderson, making due allowance for errors heretofore committed and above referred to, whenever possible. Mr. Anderson calibrated the channel with the 12-foot weir. The results found by him for these seasons, together with those obtained by the methods deduced by Mr. Williams for this period, are summarized as follows:

	G. G. Anderson.	Williams.
1903-04	19,929	16,485
1904-05	14,902	16,503
1905-06	26,962	32,551
1906-07	37,146	54,507
1907-08	9,203	14,147

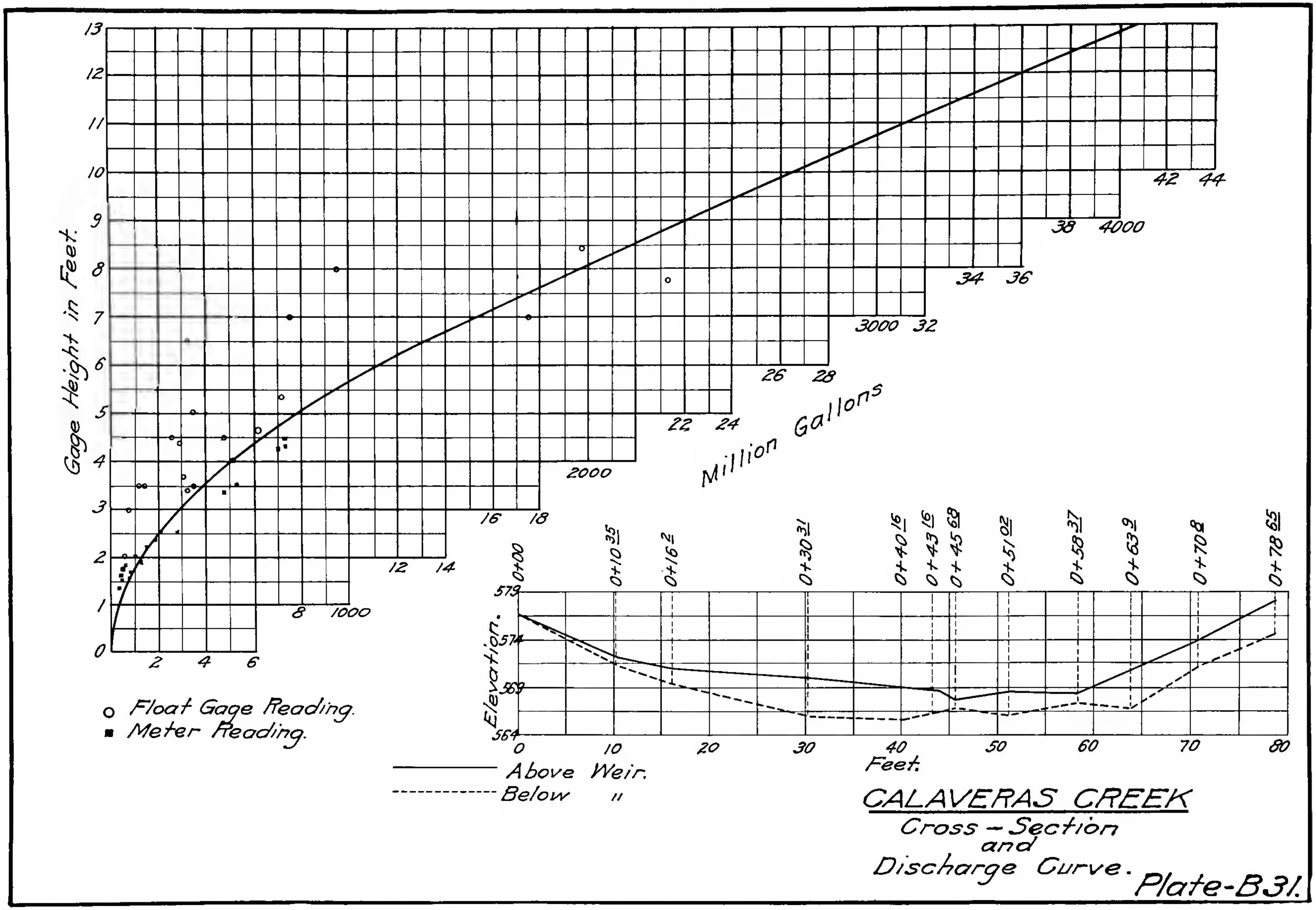
Jones Measurements.

Measurements made by Mr. P. F. Jones at Calaveras are available for the seasons 1910-11 and 1911-12.

For low water the concrete weir constructed just prior to the Williams measurements has been used. During the Williams measurements over the 12-foot weir a constant amount was added after a depth of 1′ 5″ had been reached, to account for extra quantity of water passing over the end of the weir due to a depression in the crest at that point (Plate B 29). At the beginning of the Jones measurements over this weir the depression had been filled up and made level across the entire width. (Plate B-30.)

It was intended to use a current meter for all high-water measurements, but this was found impracticable above a gage height of 6½ feet because of drift and excessive velocity of the water. In using the current meter the average vertical velocity was determined by lowering and raising the meter from the surface of the water to the bottom of the stream and back to the surface at a uniform rate. The vertical velocities were determined at intervals of 5 feet, and a summation of discharge made, using products of the vertical velocities and the area to which they applied. The section used for meter work was under the suspension bridge, directly upstream from the concrete measuring weir.

The float measurements were taken over a



THE DISCHARGE CURVE FOR CALAVERAS CREEK (JONES MEASUREMENT) IS DETERMINED FROM CAREFUL CURRENT METER AND FLOAT MEASUREMENTS.

course of 100 feet just above the suspension bridge. The course has a rocky point projection on one side, and is not a particularly favorable one. Floats were started at different points of the stream surface width, and note taken of the time consumed in passing over the 100-foot course and the portion of the stream width they traversed. By plotting these, the surface velocities at various portions of the streams were determined. The average vertical velocity was assumed to be 6-10 of the surface velocities in all cases. This factor was used because of the character of the stream bed.

From the gagings, both by meter and floats, a discharge curve (Plate B 31) was constructed to which gauge rod readings were applied. During storms half-hourly gage readings were taken.

The results of the 1910-11 gagings give a run-off of 56% of the total mean area rainfall for that year. This seems rather high, though it can be explained by the abnormal character of the rainfall during the season of 1910-11. Practically all the rain came in three storms closely following one another, the first occurring after the ground was fairly well saturated. The intensities of the storms were also abnormal. These two factors satisfy the condition for a maximum run-off from the recorded rainfall.

Plate B 31 shows the cross-section of the Calaveras Creek at the place of gaging by Jones, together with the discharge curve developed from his gagings. Plate B 36 shows the location of gage for measuring stream.

The formula used for the discharge over the weir was the one used in the Williams measurements. (Plate B 25.)

Measurements of Flow of the Arroyo Valle.

Gagings of the Arroyo Valle at the damsite were taken by the Spring Valley Water Company over a period of about 4 years, covering the seasons of 1904-5 to 1907-8, inclusive. Although diligent search was made through all the records of the Spring Valley Water Company we were unable to find these gagings.

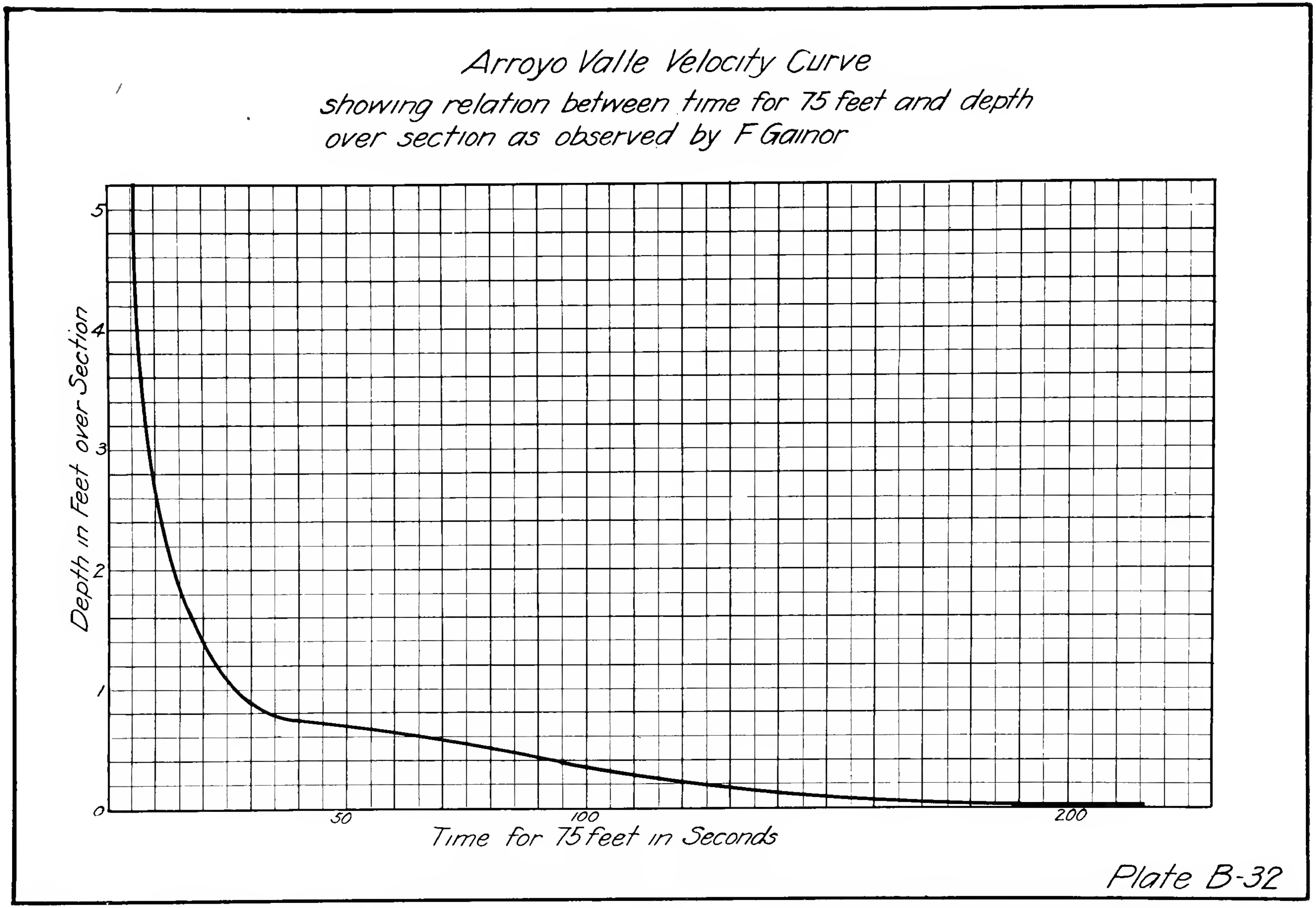
Subsequently a copy of most of the records taken at Arroyo Valle was obtained from Mr. F. Gainor, the watchman who took the measurements. This copy covers all the flood seasons of these three years though not all of the low water periods. While it is not the original document, it is an authentic copy of the same, made by the man who took the measurements at the time they were being taken, and is accepted as correct. Estimates have been made of the low water flow not contained in the record, by comparison with other recent low water flow records.

Careful cross-section measurements of the channel at the gaging station were made by Mr. L. B. Cheminant. This course was laid out with a length of 150 feet. During the first season the course was used over its entire length, though for the seasons following only the upper 75 feet was used. As in the case of the Williams and the Hadsell stream measurements, the maximum surface velocity was obtained by recording the time it took a float to pass over the length of the course along the thread of maximum surface velocity at varying stages. Simultaneously with the velocity measurements, the depth of water on the gage rod was also recorded. The course was a very good one except that the cross-section of the stream at this point contains gravel of a considerable area, permitting some underflow to pass without measurement.

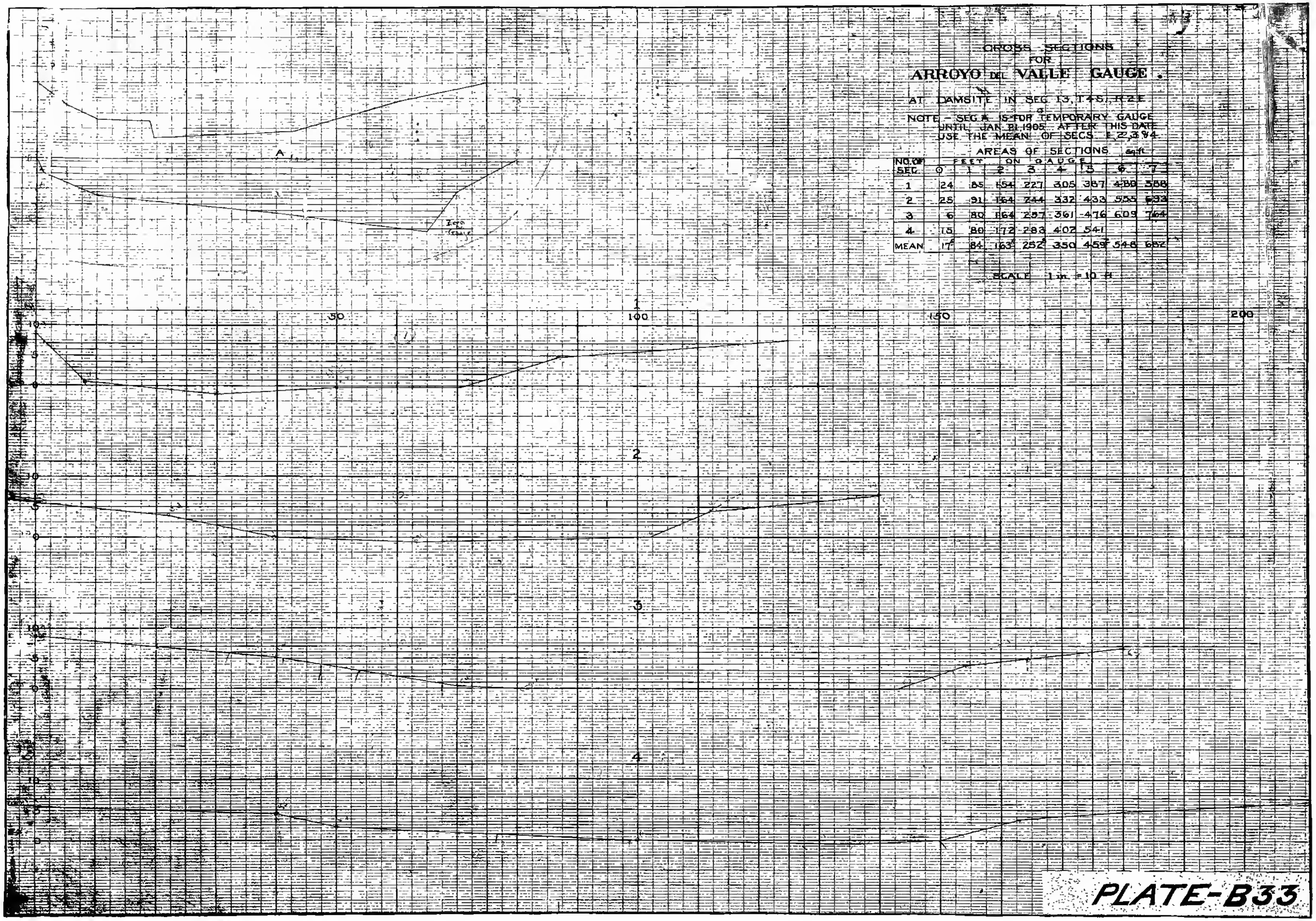
Methods Used in Computing Flow of Arroyo Valle.

In arriving at the discharge represented by these gagings, several methods of computation were used resulting in approximately the same quantities as that which was finally used and is here described in detail.

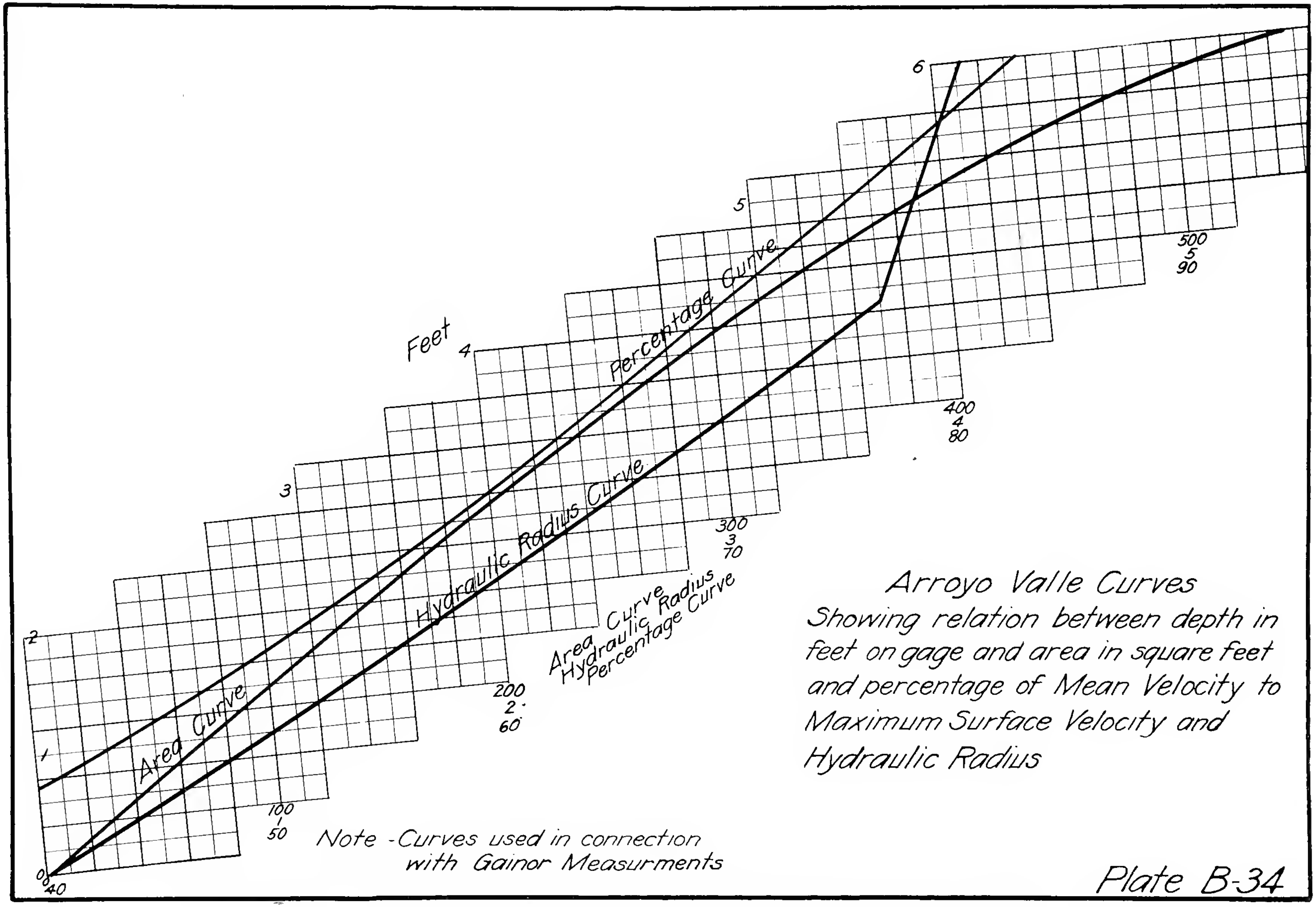
The gagings and recorded time show some discrepancies. For instance, from the table of gagings on Jan. 14th, 1906, we have a gage height of 3′ 0″ corresponding to a time of 20 seconds for a distance of 75 feet, and on Jan. 31st, 1907, we have a gage height of 0.90 feet and a time of 20 seconds for 75 feet. These differences in depth corresponding to the same time may be accounted for by the possibility of the recorder placing the float in a part of section outside of the path of the maximum surface velocity, or by the direction of the wind, or a combination of both. A wind blowing upstream would retard the velocity of the float, while a wind blowing downstream would increase it. In order to overcome this exigency



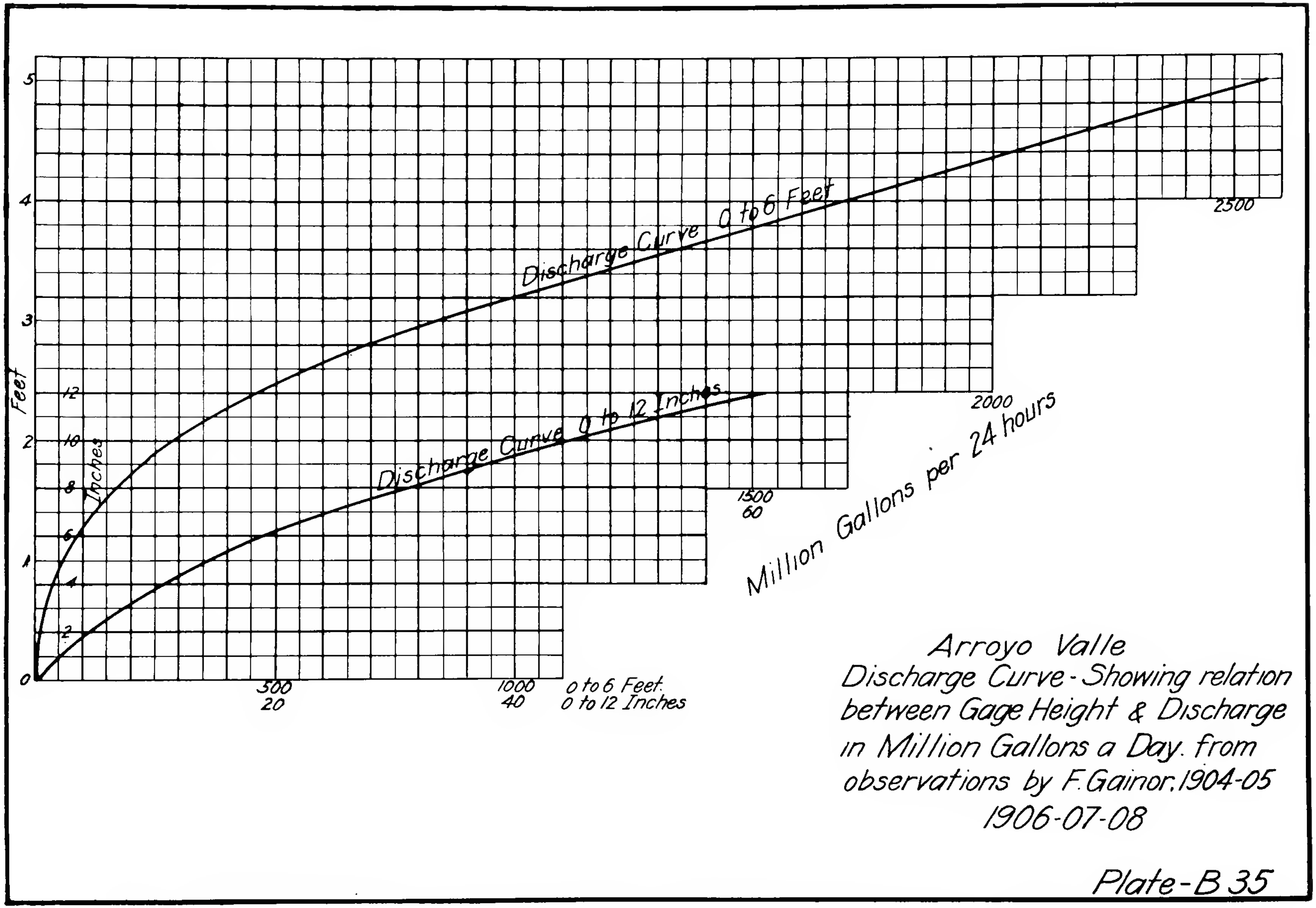
THE SURFACE VELOCITY AND THE STREAM FLOW INCREASES VERY RAPIDLY WITH THE DEPTH OF THE WATER.



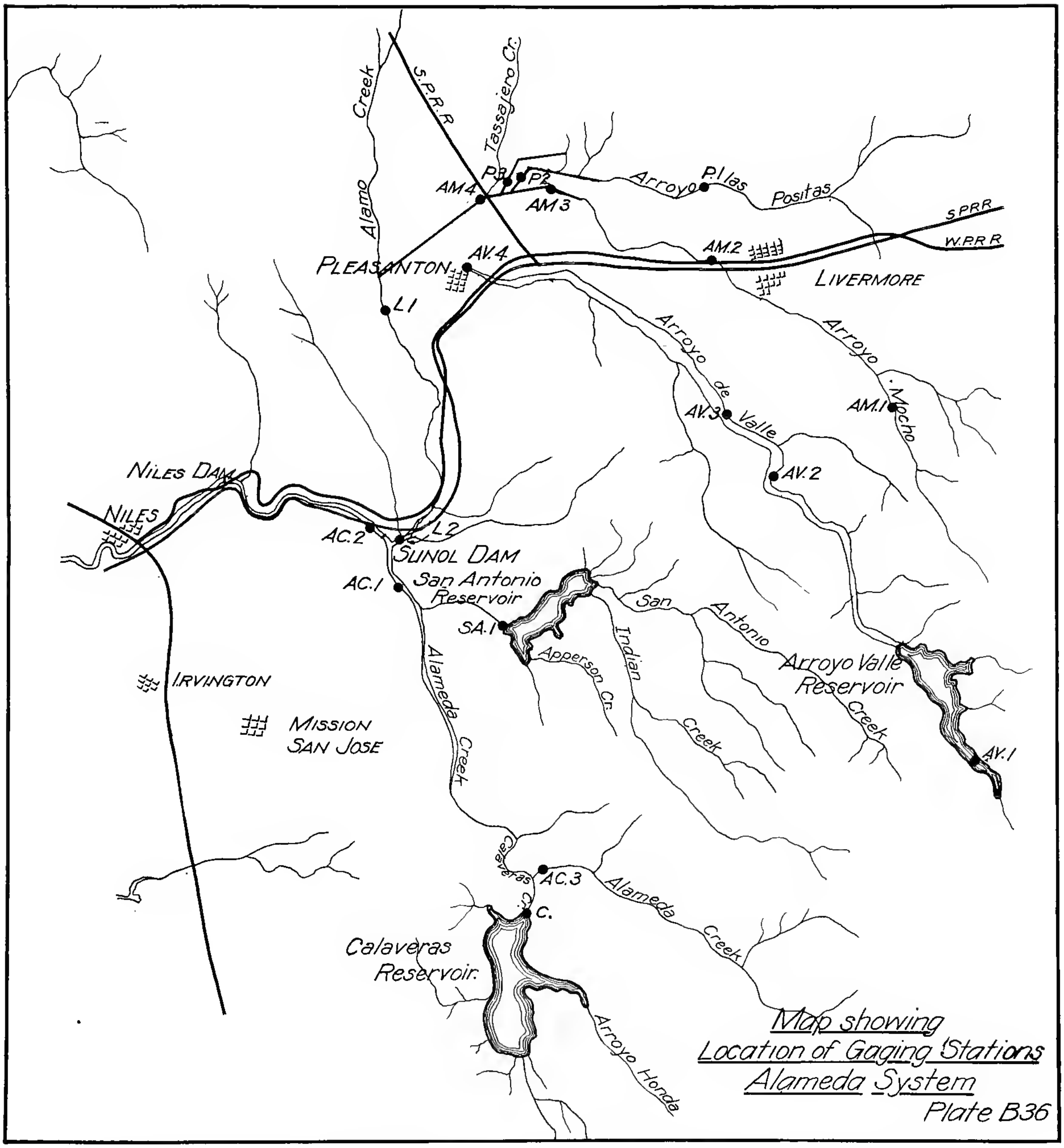
NO. OF SEC.	0	1	2	3	4	5	6	7
	FEET	ON	GAUGE					
1	24	85	154	227	305	387	488	588
2	25	91	164	244	332	433	555	633
3	6	80	164	257	361	476	609	764
4	15	80	172	283	407	541		
MEAN	17	84	163	252	350	459	548	662



THE CO-EFFICIENTS APPLIED TO THE SURFACE VELOCITIES DEPEND UPON THE HYDRAULIC RADIUS.



DISCHARGE CURVE OF ARROYO VALLE FROM FOUR YEARS CAREFUL STREAM MEASUREMENTS.



STREAM GAGINGS ARE BEING MADE AT MANY PLACES IN THE ALAMEDA SYSTEM.

a time curve (Plate B 32) was very carefully drawn as a mean of all observations, the coordinates of each observation being represented by depth of the gage and time required to traverse the 150-foot course. From this time curve the maximum surface velocities were computed for various depths as indicated by gage rod readings.

Stream Section Very Favorable for Good Results.

A glance at the stream bed sections (Plate B 33) through which the gagings were taken, will show that sections numbered 2 and 3 are very nearly identical in general conformity while sections numbered 1 and 4 differ materially in shape. It was considered logical to build up a composite of these sections giving double weight to sections 2 and 3 and correspondingly smaller significance to sections 1 and 4. After building up this composite section, the areas and the hydraulic radii for different gage heights were computed. In terms of the gage heights the areas and the hydraulic radii were plotted and smooth curves drawn through these points. From a study of Mr. C. E. Grunsky's Sacramento River investigations, as per Report to Commissioner Rose, and making similar investigations on the Arroyo Valle sections for depths of from 1 foot to 5½ feet, we find that the ratio of mean sectional velocity to maximum surface velocity varies from .43 to .80. A percentage curve was drawn between these limits, as shown on Plate B-34, and following the general trend of the hydraulic radii for these different depths. From the area and percentage curves thus obtained, a discharge curve (Plate B 35) was plotted and the quantities for the storm periods of the seasons 1904-05 to 1907-08, inclusive, were obtained. These with the addition of the estimated dry season flow are given by months in the following table:

ARROYO VALLE RUN-OFF.
From F. Gainor's Gagings
in Seasons

	1904-5	1905-6	1906-7	1907-8
	M. G	M. G.	M. G.	M. G.
July	*30	*30	*30	*30
Aug.	*30	*30	*30	*30
Sept.	*30	*30	*30	*30
Oct.	*50	*30	*30	*30
Nov.	*60	*30	*30	*30
Dec.	*200	*50	1,495	294
Jan.	*500	6,234	10,618	1,613
Feb.	589	788	1,195	1,095
Mar.	2,290	7,967	18,125	*100
Apr.	222	1,457	*100	*60
May	185.7	199	*80	*30
June	*60	36	*30	*30
Totals	4,246.7	16,881	31,793	3,372

Note: *—Indicates Estimated Quantity.

The flow for 1911-12 was made under the direction of Mr. T. W. Espy by Standard Current Meter methods.

Measurements to Determine Rapidity of Water Entering Livermore and Sunol Gravels.

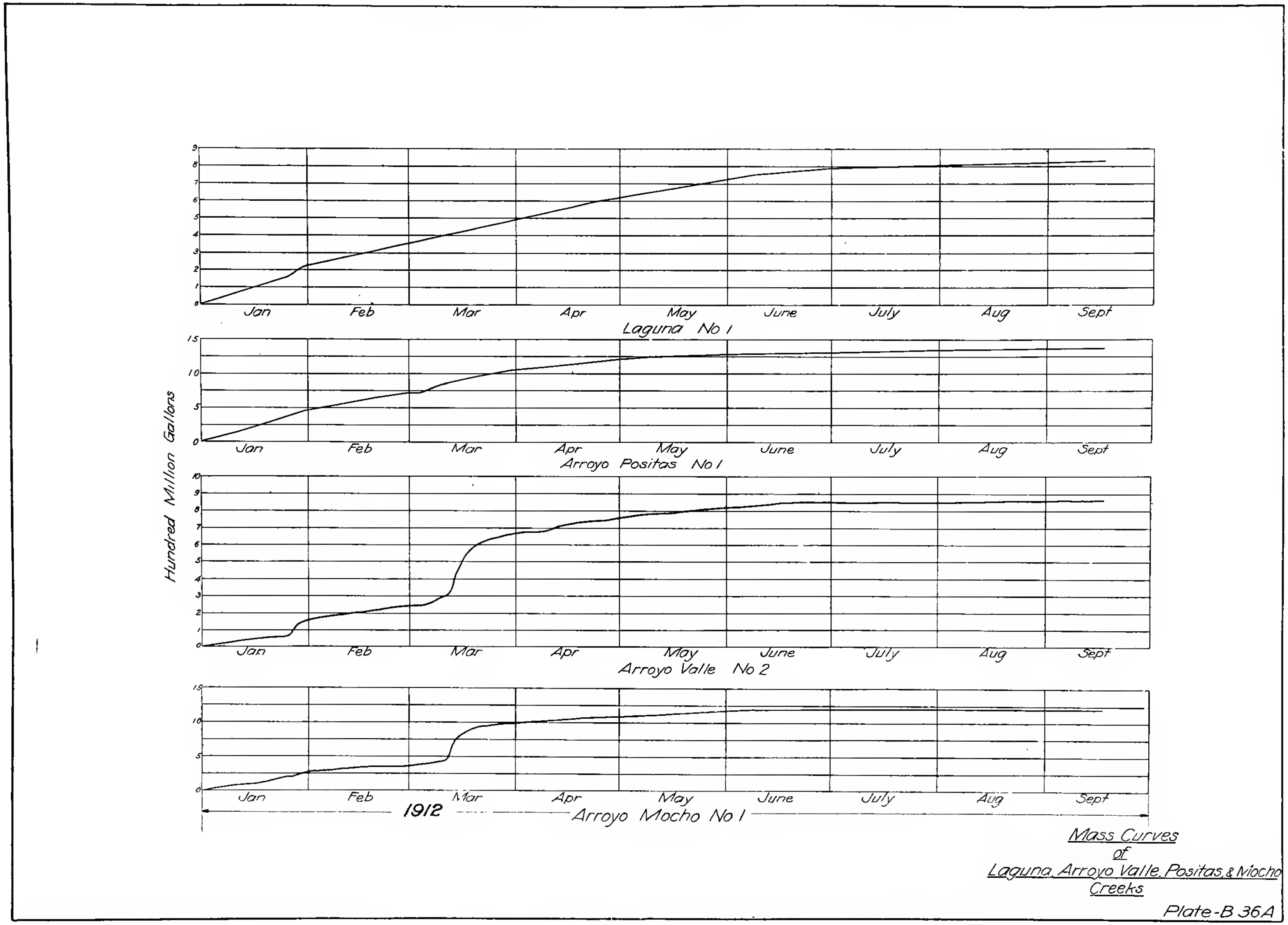
Beginning with January 1st, 1912, gaging stations were established at four places on the Arroyo Valle, three places on the Arroyo Mocho, two places on the Arroyo Positas, two places on the Laguna Creek, and one place on the San Antonio Creek. The relative location of these gaging stations is shown on Plate B 36. These measurements were taken with weirs and current meters, effort being made to obtain all fluctuations of flow.

Following is a tabulation by months of discharges in million gallons at these various stations:

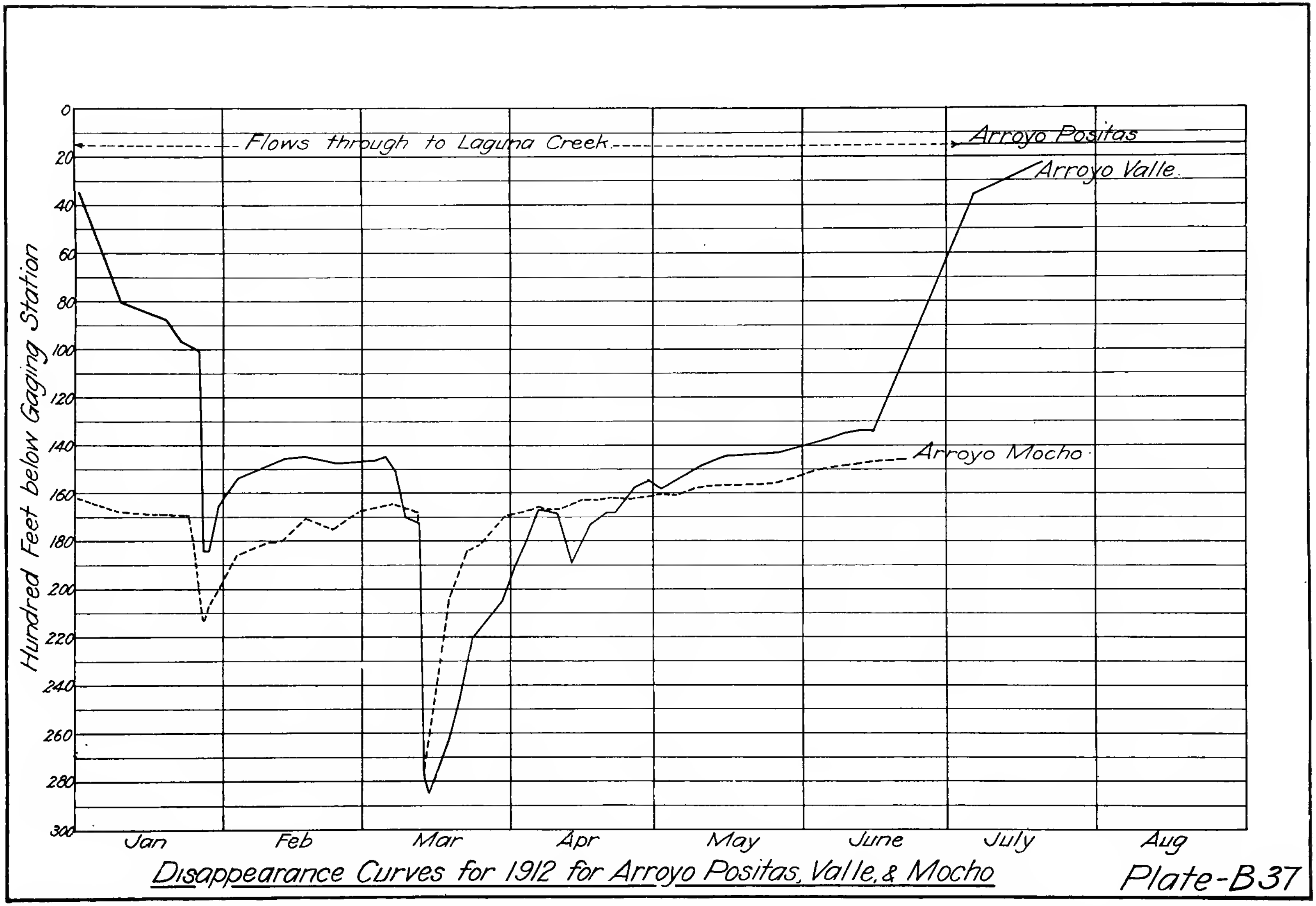
1912.	Arroyo Valle, No. 1.	Arroyo Valle, No. 2.	Arroyo Valle, No. 3.	Arroyo Valle, No. 4.	Arroyo Mocho, No. 1.	Arroyo Mocho, No. 2.	Arroyo Mocho, No. 3.	Arroyo Mocho, No. 4.	Positas, No. 1.	Positas, No. 2.	Laguna, No. 1.	Laguna, No. 2.	San Antonio,
Jan. ..	117.85	154.48	61.03	0	26.31	0	2.16	54.59	45.53	32.39	224.35	271.07	114.5
Feb. ..	62.50	78.48	35.64	0	10.19	0	.85	19.88	25.27	7.22	119.78	105.56	40.6
Mar. ..	411.77	423.63	356.58	0	62.61	0	0	23.09	35.01	9.88	153.95	162.64	202.9
Apr. ..	106.57	96.88	69.19	0	11.22	0	0	9.50	14.78	0	125.80	134.67	56.5
May ..	60.94	60.27	28.23	0	7.71	0	0	5.70	6.83	0	105.17	110.85	31.2
June ..	7.93	35.72	9.47	0	1.65	0	0	1.87	3.51	0	65.81	51.23	8.3

At all of these stations there is more or less underflow that of course is not included in these measurements.

At Arroyo Valle No. 2, located at the Cresta Blanca Bridge, bedrock is exposed on the east bank of the creek, though it does not appear in the bottom of the stream bed. The bridge at this point has two concrete piers, the south-



THE RESULTS OF MEASUREMENTS OF STREAMS ENTERING AND LEAVING LIVERMORE VALLEY FOR THE FIRST HALF OF 1912 ARE SHOWN IN THE FORM OF MASS DIAGRAMS.



THE WATER ENTERING LIVERMORE VALLEY DISAPPEARS AT VARIOUS POINTS IN THEIR STREAM BEDS. THE LOCATIONS OF THE POINTS OF DISAPPEARANCE ARE SHOWN GRAPHICALLY FOR THE FIRST HALF OF YEAR 1912.

erly pier being in the center of the trough of the stream bed, not resting on bed rock. At this gaging station there is probably less surface stream flow than at any other of the stations on the Arroyo Valle.

At Arroyo Mocho No. 1, located about 6 miles southeast of Livermore, the east bank is clay, probably the edge of a clay kidney, there being no evidence of its continuing across the stream channel. There is probably less underflow at this station than at the others in the Arroyo Mocho.

The same is relatively true of Positas No. 1.

Plate No. 36 A contains mass curves of the flows at these various stations.

Weekly observations were made of the place of disappearance of waters in the Arroyo Valle, Arroyo Mocho and Arroyo Positas. These are indicated diagramatically on Plate B 37.

Estimated Run-off from the Various Drainage Areas of Alameda System.

From the foregoing statement concerning run-off in the Alameda System it may be briefly stated that the records available are as follows:

Daily computations of flow over Sunol and Niles Dams from December, 1889, to July 1st, 1912;

Daily computations of flow at the Calaveras Reservoir site since July 1st, 1898, to July 1st, 1912, with two seasons, 1908-09 and 1909-10, and another gap of a few days duration missing;

Daily computations of flow for the rainy season at the Arroyo Valle damsite from 1904-05 to 1907-08 and from January 1st to July 1st, 1912;

Daily computations of flow from January 1st to July 1st, 1912, at each of the following stations:

4 on Arroyo Valle
2 on Arroyo Mocho
2 on Arroyo Las Positas
2 on Laguna Creek
1 at San Antonio damsite.

These latter stations are located on Plate B 36. Were storage facilities adequate in the Sunol Valley to regulate the flow of the streams in the Alameda System, the ascertainment of the safe dependable yield from that system based on the 23 years' continuous record of stream flow would be a simple matter.

No such simple regulation exists, however, and it is necessary to regulate the flow at various points within the drainage area, viz., at the three surface storage reservoirs, Calaveras, San Antonio and Arroyo Valle, and at the two underground storage reservoirs, at Livermore Valley and Sunol Valley.

The flow tributary to all these various storage points is not accurately known and must be estimated from such data as is available. The data includes that gathered at the three Peninsula Reservoirs, as well as that—heretofore mentioned—gathered in the Alameda System.

Flow from Each Catchment Area Estimated for the Last 63 Years.

To ascertain the run-off from each of the drainage areas for each year of the 63-year period, recourse was had to the use of run-off curves, obtained by uniting points representing run-off in adopted units (in this case the units being million gallons per square mile per season) for each progressive increase in rainfall.

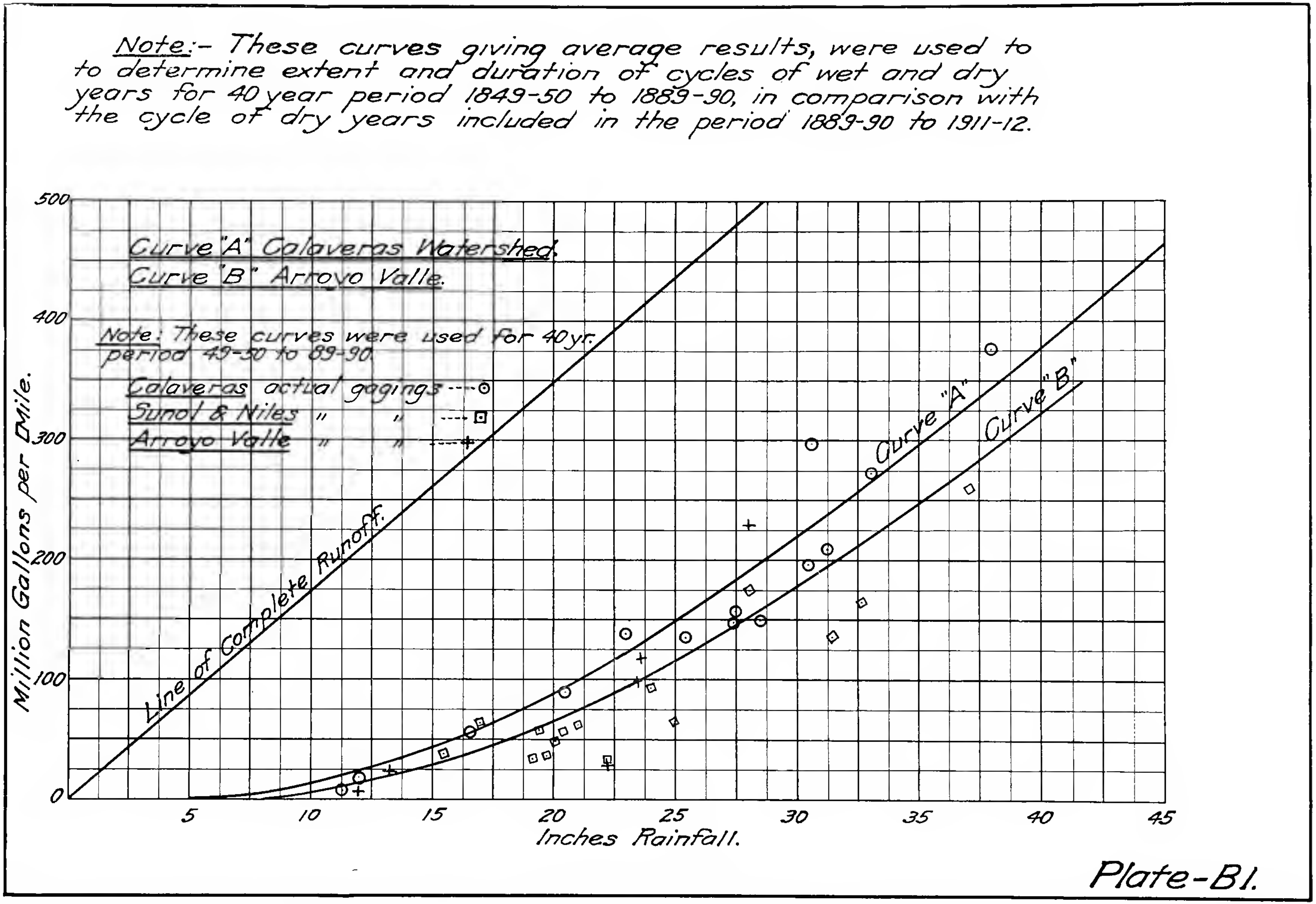
Since the run-off from any drainage area depends upon a great number of controlling factors, as for example the condition of the surface upon which the rain falls, temperature, wind, vegetation, degree of evaporation, etc., total precipitation is never fully realized in run-off. The ideal run-off curve should include all these factors, and should consider as well the very important element of rainfall distribution, in order to determine the true relation with reference to complete run-off.

In the practical consideration of run-off it is found impossible to differentiate all the methods of rainfall disposal.

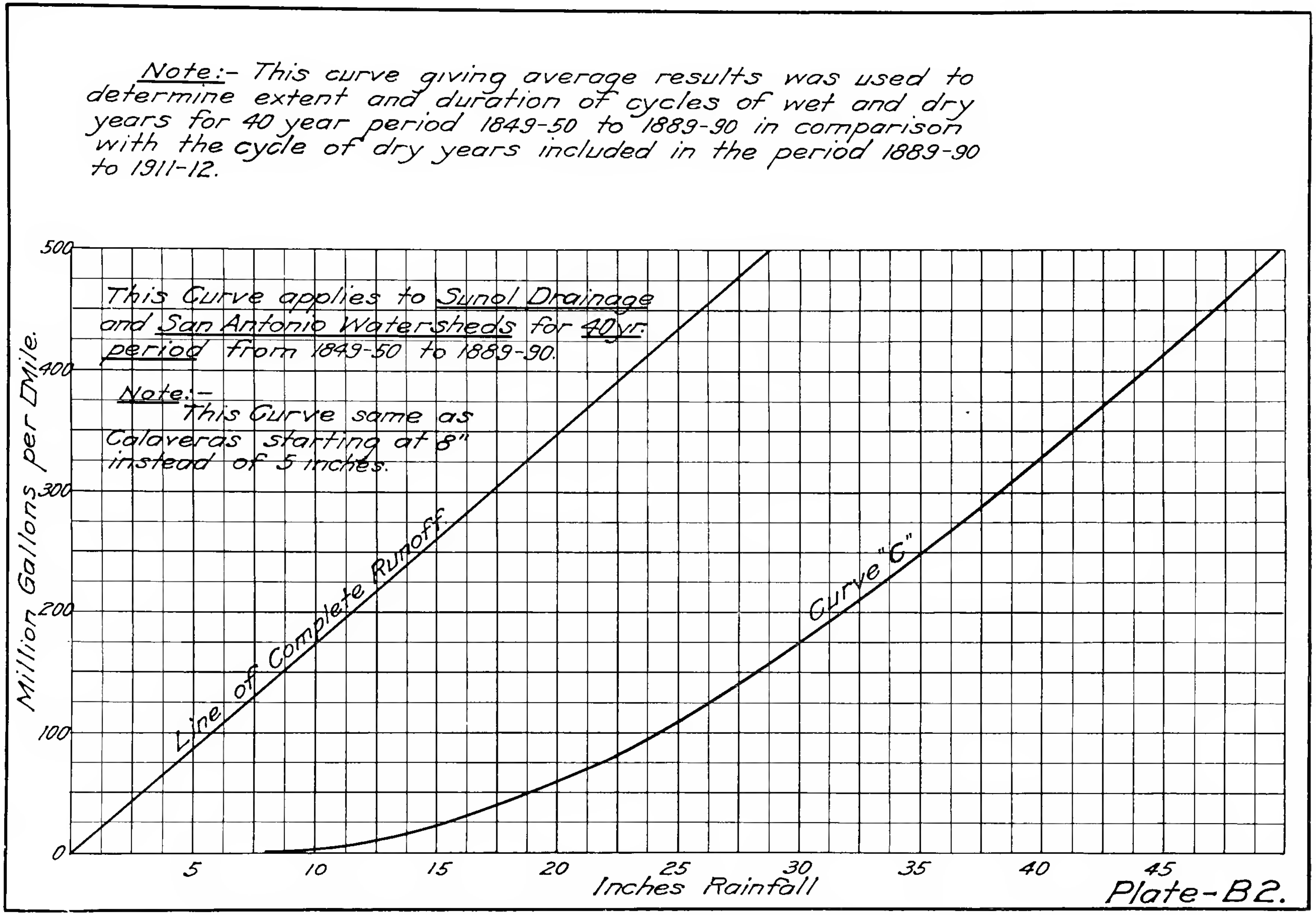
Evaporation, wind and atmospheric pressure varies from year to year. Evaporation also varies with different classes of vegetation and from different kinds of land surface.

Because of the influence of these factors it is also impossible, even if the data were at hand, to determine the run-off due to the various quantities, rates and intensities of rainfall.

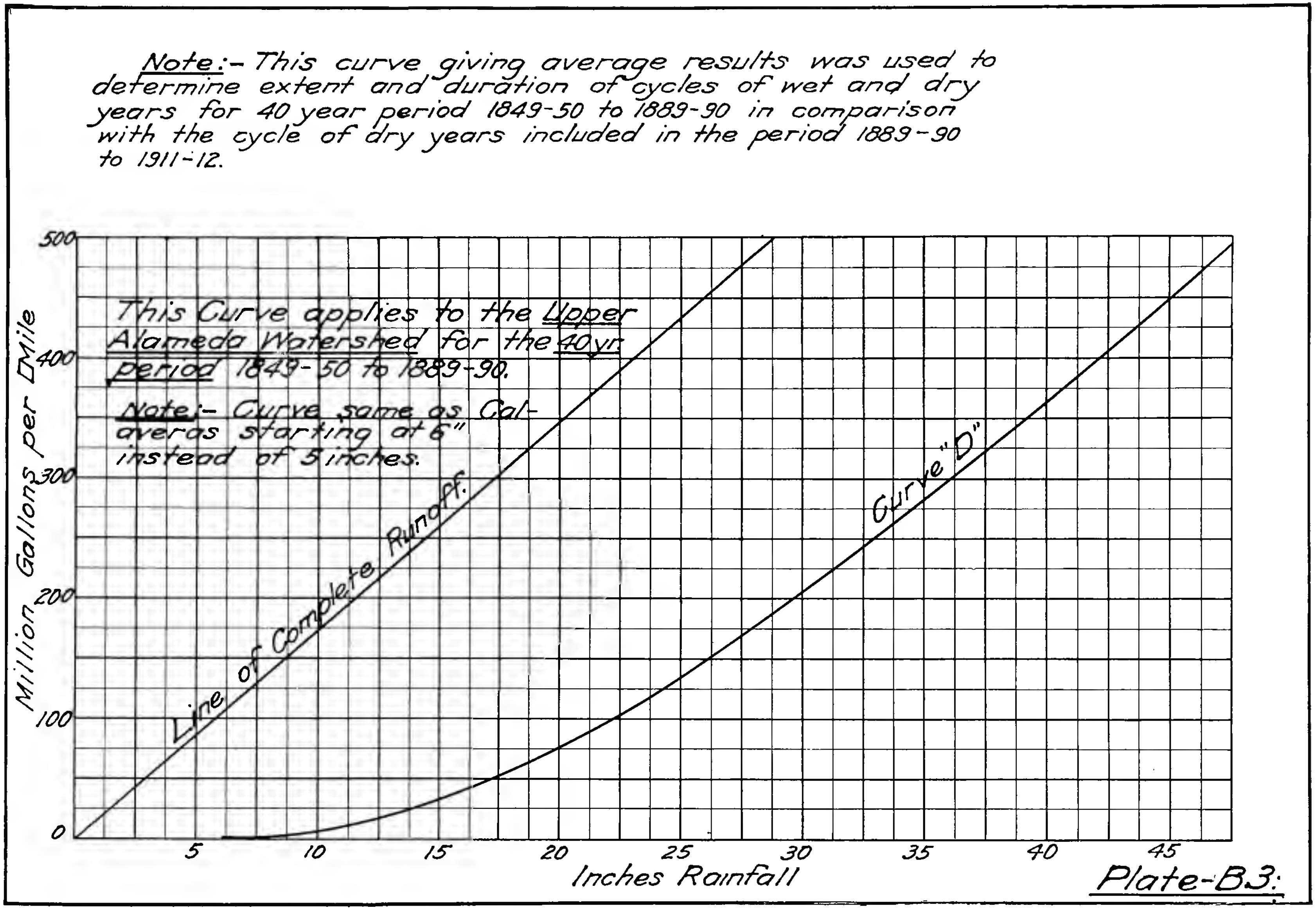
In the construction of the run-off curves to apply to the different drainage areas in the Alameda System from 1849-50 to 1889-90 (a period of 40 years), the available run-off data during the 23-year period from 1889-90 to 1911-12, as well as the run-off data for the Calaveras



SHOWING THE RELATION BETWEEN RAINFALL AND RUN-OFF CONDITIONS DETERMINED FROM ACTUAL GAGINGS AT CALAVERAS AND AT ARROYO VALLE.



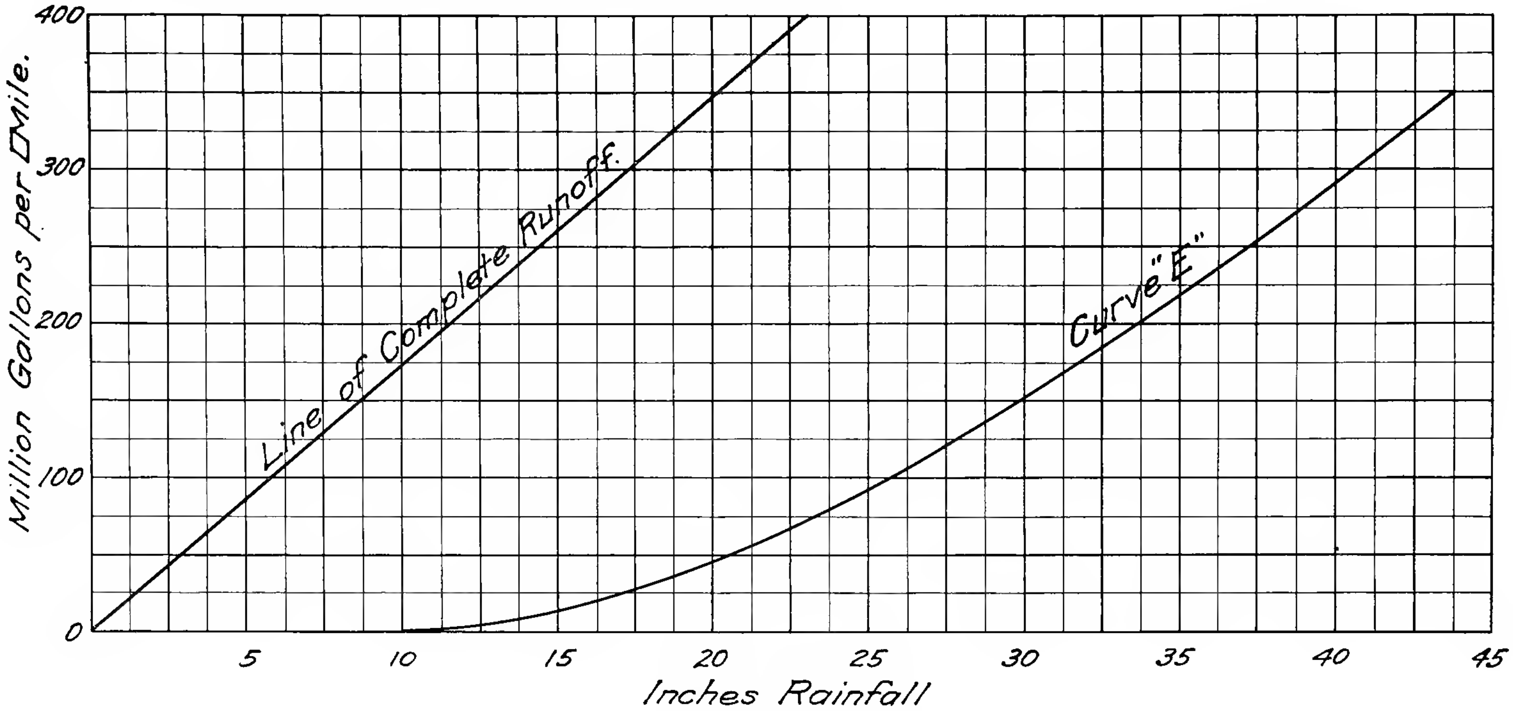
AVERAGE RELATION BETWEEN RAINFALL AND RUN-OFF USED FOR SAN ANTONIO WATERSHED FOR FORTY YEARS PRIOR TO MEASUREMENTS IN THE ALAMEDA SYSTEM.



CURVE "D" WAS USED TO DETERMINE RUN-OFF FROM THE UPPER ALAMEDA FOR FORTY YEARS PRIOR TO MEASUREMENTS IN THE ALAMEDA SYSTEM.

This Curve applies to Livermore Drainage for 40 yr. period from 1849-50 to 1889-90.

Note:- This curve is the same as Arroyo Valle starting at 10" instead of 8 inches.



Note:- The curve giving average results were used to determine extent and duration of cycles of wet and dry years for 40 year period 1849-50 to 1899-90 in comparison with the cycle of dry years included in the period 1889-90 to 1911-12.

Plate-B4.

CURVE "E" WAS USED TO DETERMINE RUN-OFF FOR LIVERMORE DRAINAGE PRIOR TO MEASUREMENTS IN THE ALAMEDA SYSTEM.

Creek for the years 1874-75, 1875-76 and 1876-77 as found in the Municipal Reports, were used.

Average Results Used Prior to Time of Measurements on Alameda Creek.

The total run-off in each drainage area was reduced to run-off per square mile and plotted with reference to the estimated mean area rainfall over the corresponding drainage area. Curves were then taken representing mean progressive lines of run-off for progressive increases in depths of total rainfall. From rainfall and run-off data at hand, and from observations of the topographical features of the Alameda System it would appear that in the beginning of the rainy season the first five inches of normal rain would produce no run-off at Calaveras, and that no run-off would be produced from the Upper Alameda, San Antonio, Sunol Drainage, Arroyo Valle and Livermore Drainage, until after 6 inches, 8 inches, 8 inches, 8 inches and 10 inches, respectively, of normal rainfall had fallen upon these various drainage areas.

These points were taken as starting at the lower end of the run-off curve for each drainage area. The run-off curves thus constructed, together with points used, are plotted on Plate B-1. These two curves "A" and "B", respectively, represent the mean run-off curves for Calaveras and Arroyo Valle drainage areas.

Upon carefully considering the normal rainfall, characteristics of drainage areas, and the probable quantity of rainfall lost before run-off begins on the various areas, judgment dictated the use of curves of the same shape as curves "A" and "B", but starting with greater loss in rainfall before run-off begins as noted above.

Thus the run-off curve adopted for Upper Alameda, San Antonio and Sunol drainage is the same as the Calaveras curve, but started at 6 inches, 8 inches and 8 inches for each of the respective drainage areas, instead of at 5 inches for the Calaveras curve; and the Arroyo Valle curve (Curve "B" on Plate B-1) was used for the Livermore Drainage with the exception that it was started at 10 inches instead of at 8 inches. The curves thus constructed for the various drainage areas are plotted on Plates B 2, 3 and 4.

By applying the mean area rainfall for each drainage area for each year of the 40-year period 1849-50 to 1888-89 to the run-off curve adopted for each drainage area, the probable annual discharge from that area was determined.

The quantities so obtained are summarized as follows:

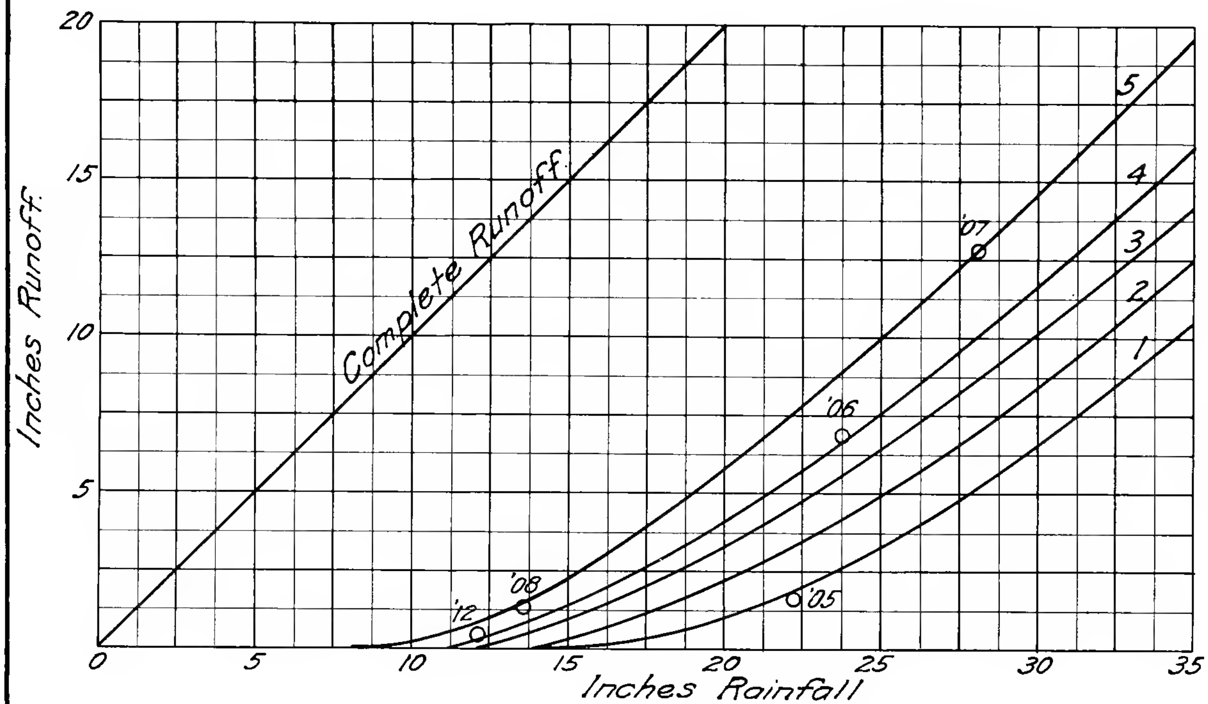
PROBABLE ANNUAL RUN-OFF IN M. G. FOR EACH SEASON NAMED FROM:

	Calaveras.	Upper Alameda.	San Antonio.	Sunol.	Arroyo Valle.	Livermore Dr.
Sq. Miles.	98.3	35.32	38.70	49.08	140.80	258.34
Season						
1849-50	41,244	10,772	9,076	10,796	27,388	32,035
1850-51	1,179	71	19	0	70	0
1851-52	13,860	2,895	2,244	2,601	6,055	5,426
1852-53	40,890	12,200	10,256	12,270	31,190	37,200
1853-54	22,510	5,470	4,412	5,202	12,532	13,175
1854-55	22,312	5,430	4,373	5,154	12,390	12,660
1855-56	18,283	4,351	3,464	4,024	9,505	9,559
1856-57	15,334	3,532	2,767	3,190	7,350	7,233
1857-58	18,578	4,450	3,522	4,073	9,768	9,817
1858-59	19,364	4,660	3,715	4,319	10,915	10,330
1859-60	19,462	4,680	3,715	4,368	10,279	10,590
1860-61	14,941	3,421	2,670	3,092	7,252	6,975
1861-62	71,950	20,680	17,918	21,790	58,085	74,400
1862-63	6,389	1,183	909	1,031	6,899	1,290
1863-64	2,949	371	271	294	493	0
1864-65	24,082	5,950	4,799	5,693	13,728	14,210
1865-66	20,641	5,010	3,986	4,711	11,194	11,370
1866-67	45,120	11,900	10,042	12,023	30,556	36,436
1867-68	53,380	14,300	12,229	14,720	37,878	46.240
1868-69	17,890	4,190	3,328	3,877	9,151	9,300
1869-70	14,352	3,248	2,554	2,944	6,758	6,458
1870-71	6,881	1,308	987	1,129	2,323	1,292
1871-72	35,975	9,049	7,547	8,932	20,699	25,834
1872-73	8,843	1,801	1,471	1,865	3,309	2,583
1873-74	24,082	5,951	4,644	5,202	9,927	14,210
1874-75	6,291	1,254	929	1,080	2,873	1,292
1875-76	37,255	11,656	8,650	8,540	25,909	31,260
1876-77	1,867	424	193	74	634	.....
1877-78	27,031	5,952	5,148	6,626	14,009	15,240
1878-79	16,022	2,755	2,380	3,092	4,407	5,425
1879-80	18,872	5,369	3,909	4,024	11,617	11,370
1880-81	15,728	4,203	3,212	3,582	10,068	8,783
1881-82	15,531	3,108	2,302	2,502	5,632	5,425
1882-83	20,446	2,755	2,438	3,239	6,266	4,909
1883-84	49,740	9,995	8,746	11,042	25,557	28,160
1884-85	24,770	2,155	2,148	3,239	4,435	3,617
1885-86	23,789	7,206	5,612	6,184	14,856	18,340
1886-87	10,420	1,925	1,548	1,865	3,777	2,842
1887-88	15,335	2,720	2,206	2,650	5,843	4,909
1888-89	9,633	2,296	2,051	2,944	6,477	3,100

It must be noted that these quantities are only average quantities produced by seasonal amounts

Curves showing relation between Rainfall and Runoff on Arroyo Valle and Livermore Drainage Watershed, 140^{0} + 258^{34} = 399^{14} □M. for 23 yr. period from 1889-90 to 1911-12.

Note:- For Livermore Drainage put '09 on Curve #3, put '90 on Curve #2, put 1897 on Curve #4.

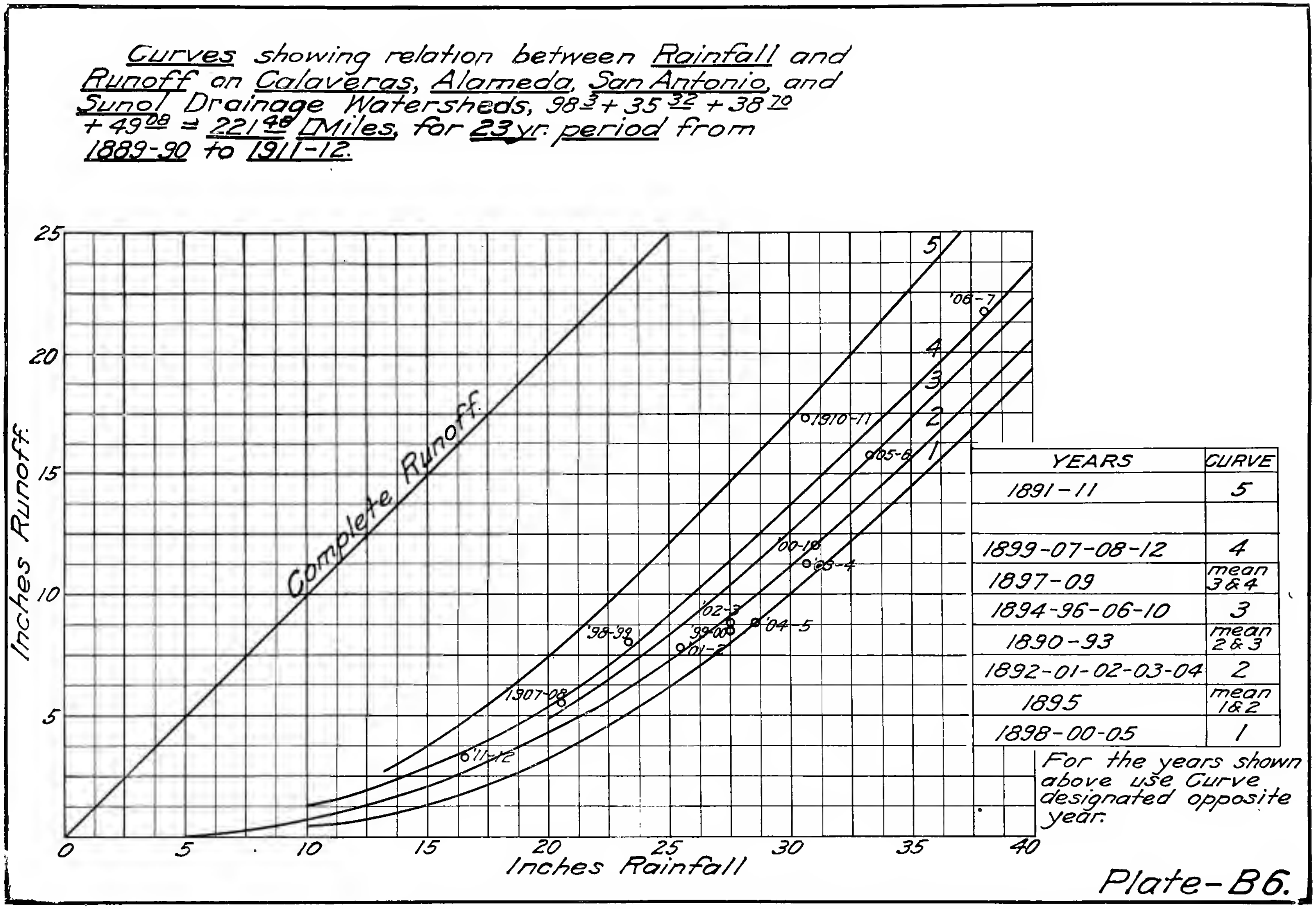


FOR YEARS USE	CURVE
'91-'07-'08-'11	5
'98-'99-'03-'06-'12	4
'97-'09	mean 3&4
'94-'96-'02-'04-'10	3
'90-'93 use mean	2&3
'92	2
'95-'00-'01-'05	1

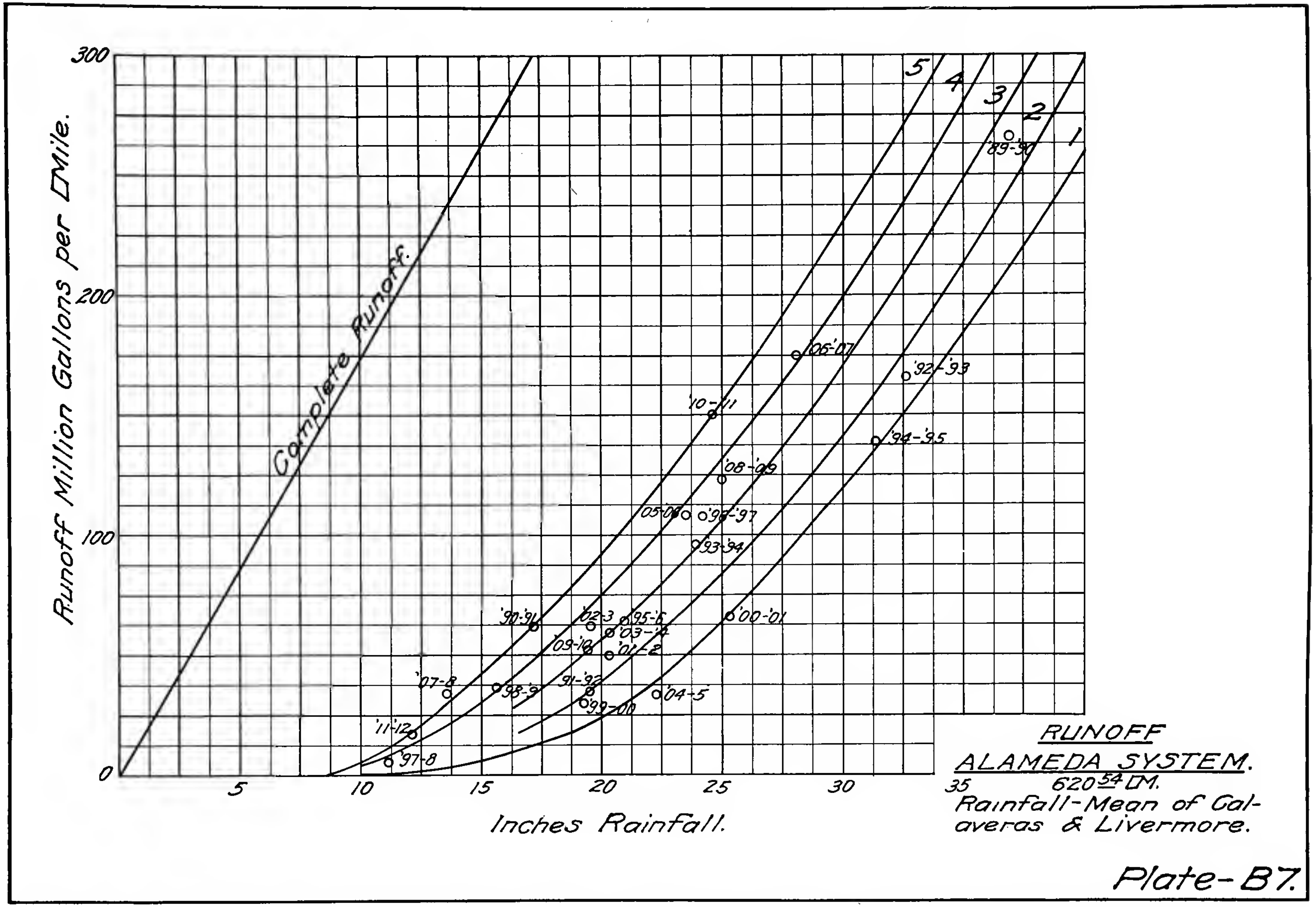
For the years shown above use curve designated opposite year.

Plate-B5.

THE POSITION OF CURVES FOR GROUPS OF YEARS WAS DETERMINED FROM ACTUAL GAGINGS AND COMPARISON WITH ADJACENT CATCHMENT AREAS.



THE POSITIONS OF CURVES GROUPING THE YEARS ACCORDING TO RUN-OFF CONDITIONS WERE DETERMINED FROM ACTUAL MEASUREMENTS.



THE YEARS HAVE BEEN GROUPED ACCORDING TO RUN-OFF CONDITIONS BY ACTUAL STREAM MEASUREMENTS OVER A PERIOD OF TWENTY-THREE YEARS.

of rainfall, and entirely disregard the influence upon the run-off, of factors such as rates and intensities of rainfall, evaporation, etc., noted above.

It is believed, however, that the results are invaluable in that they indicate in a long series of years the frequency of maximum and minimum run-off, their departure from the normal, and what is perhaps more important, the longest continued cycle of dry years.

As will be shown later from mass diagrams of these results, compared with mass diagrams of results of run-off from each of the drainage areas during the 23-year period from 1889-90 to 1911-12, no greater period of drought existed in the 63 years than that which occurred in the latter 23 years of that period.

More Accurate Results Obtained for 23 Years of Alameda Measurements by Grouping Years.

In constructing the run-off curves to apply to the various drainage areas during the 23-year period from 1889-90 to 1911-12, more data was available in the shape of run-off records making it possible to characterize certain years as normal or abnormal in run-off.

In plotting the run-off in inches for the entire Alameda System resulting from practically similar rainfalls it was noted that the season 1911-12 was more productive of run-off due to small rainfall (11″ to 12″) than was the year 1897-98, and that for years of rainfall slightly above normal (about 25″), the rainfall during the season of 1910-11 produced over twice the quantity which was produced by the same precipitation in the season 1900-01. In continuing these comparisons of run-off at Niles and Sunol Dams, Calaveras, Arroyo Valle and the Peninsula, it was found practical in the 23-year Niles and Sunol records, by the use of 5 lines or curves to classify certain years with respect to their productivity as affected by normal and abnormal run-off conditions.

The run-off at Calaveras for the 12 seasons, and at Arroyo Valle for the 5 seasons, when plotted assumed practically the same relation with respect to years as did the Niles and Sunol records, thus clearly indicating the propriety of characterizing the various years as normal or abnormal in run-off due to the rainfall and of making 5 different classifications of years as in the case of the entire Alameda System. To complete the 23-year record at Calaveras and Arroyo Valle from the five curves deduced for each, the year whose run-off was desired was given a position corresponding to one of the five curves at Calaveras and at Arroyo Valle as that year occupied with reference to the 5 curves of the entire Alameda System. (Plate B 7.)

As has been noted above the run-off curves for Upper Alameda, San Antonio and Sunol drainage conform in appearance to the Calaveras curve but were started later with respect to total rainfall; and that to Livermore drainage was applied a similar form of run-off curve to that applied to Arroyo Valle, but with greater loss of rain before starting run-off. Thus owing to the fact that run-off does not start in the Upper Alameda until after 6 inches of normal rain has fallen, that San Antonio does not start run-off until after 8 inches of normal rain has fallen and that Sunol Drainage run-off does not commence until after 8 inches of normal rain has fallen, the five curves of Calaveras have been shifted horizontally one inch, three inches and three inches respectively to meet the conditions of run-off of Upper Alameda, San Antonio and Sunol Drainage.

In like manner the 5 curves of the Arroyo Valle have been shifted horizontally two inches to meet the conditions of run-off from the Livermore Drainage, where 10 inches of normal rainfall occurs without producing run-off. It is to be noted that the middle or approximate mean line of the 5 curves used in the 23-year period 1889-90 to 1911-12 for each of the drainage areas is identical with the single curves (Plates B 1, 2, 3 and 4) used for the 40-year period 1849-50 to 1888-89 for each of the corresponding drainage areas.

The 5 curves adopted for each drainage area are plotted on Plates B 5 and 6.

By applying the estimated area rainfall for each year to the proper curve there is obtained the total quantity of run-off for each drainage area for each year of the 23-year period from 1889-90 to 1911-12.

The quantities so obtained are summarized as follows:

PROBABLE ANNUAL RUN-OFF IN M. G. FOR EACH SEASON NAMED FROM:

	Calaveras.	Upper Alameda.	San Antonio.	Sunol.	Arroyo Valle.	Livermore Dr.
Sq. Miles.	98.3	35.32	38.70	49.08	140.80	258.34
Season						
1889-90..	46,180	15,960	13,960	17,700	36,700	47,150
1890-91..	15,900	4,145	2,187	2,900	11,624	10,115
1891-92..	14,530	4,298	2,187	2,346	4,894	4,945
1892-93..	36,760	11,970	8,210	8,743	32,300	20,600
1893-94..	26,850	7,675	4,879	4,692	14,070	10,115
1894-95..	29,930	10,740	7,066	7,464	19,088	19,104
1895-96..	18,380	5,219	2,860	3,199	9,789	10,115
1896-97..	25,220	8,350	5,216	5,544	15,900	20,200
1897-98..	3,250	737	202	426	734	.....
1898-99.	*13,720	3,623	2,692	2,985	4,160	4,495
1899-00.	*14,560	3,684	2,524	2,388	2,447	3,367
1900-01.	*20,531	6,601	5,048	6,653	8,565	6,293
1901-02.	*13,391	3,530	2,524	2,559	8,076	5,619
1902-03.	*15,471	4,144	2,557	2,772	11,745	11,237
1903-04.	*19,380	5,219	3,230	4,435	8,565	8,990
1904-05.	*14,902	4,973	3,701	3,583	*4,247	6,743
1905-06.	*26,962	6,140	5,034	6,653	*16,881	22,474
1906-07.	*37,146	9,579	8,211	10,670	*31,793	43,600
1907-08..	*9,203	2,149	1,682	1,919	*3,372	4,495
1908-09..	29,920	8,719	5,889	7,677	17,130	20,210
1909-10..	12,990	3,377	2,860	2,985	7,340	8,540
1910-11.	*29,700	9,364	8,413	12,539	23,982	25,620
1911-12..	*5.554	1,382	1,346	1,962	*970	.....

* Actual Gagings.

Appendix C.

DISCHARGE OVER SUNOL AND NILES DAMS.

BY

F. C. Herrmann,

Chief Engineer, Spring Valley Water Company.

Records of the depth of water over the Niles Dam have been kept by the Spring Valley Water Company from November, 1889, to October, 1900, and over the Sunol Dam from October, 1900, to the present time. From these records computation of the volume of run-off water at these dams has been made by applying a weir formula of the ordinary Francis type, the units used being in inches for linear dimensions, and gallons per day for rate of flow, thus:

$$\text{for Niles } Q=4200\ bh^{3/2}$$
$$\text{for Sunol } Q=4400\ bh^{3/2}$$

These formulae do not take into consideration either the impulse of the water due to its velocity as it approaches the weir, the retarding effect of submergence below the weir, nor the shape of the weir crest. No measurements have been made to determine the effect of these factors, it being assumed that in the aggregate they offset one another.

Neither of the dams is ideal for measuring the flow of water, and the great number of irregularities entering into the problem make it very complex. The method by which gage rod readings have been taken adds further to its complexity. At the Niles Dam the readings, except for low water flow, have been taken at the forebay, which is well below the crest of the dam. At the Sunol Dam the readings for other than low water flow have been taken at a series of points, which progress upstream from the crest of the dam as the stage of the water increases to a certain depth, after which the measurements were taken just above the crest. All rod readings for both dams are well within the curve of water surface as it falls over the dam.

Results of experiments on various types of dams of irregular cross-section have been published, which show coefficients that vary between wide limits for the different types considered. A study of these results impresses one with the fact that large variation in the coefficient exists for comparatively insignificant changes in cross-section of the dam. None of the types of which we have published experimental results are identical with either the Niles or the Sunol Dam in cross-section. Theoretical solution of the flow over these dams must, therefore, be built up as a modification of some standard weir formula, changing it by combining the effects of the various irregularities as expressed in published experimental data, with weirs containing one or more of these irregularities, together with computations of the forces due to accelerations from irregularities not expressed by these experimental data.

As noted above, for some stages of flow the Niles and Sunol Dams must be considered as submerged weirs. Standard formulae for weirs are unreliable when the difference in elevation of the water above and below the weir, or the afflux, is less than 35% to 50% of the depth of water over the weir.

Accurate Results Determined by Experiments With Model Dams.

From the foregoing it is seen that theoretical solution, unsupported by the proper experimental data, will be clothed with uncertainty. By rea-

son of this, the services of Prof. J. N. Le Conte, of the University of California, were secured for the purpose of making the necessary experiments to determine the proper discharge curves for the two dams under the conditions of gage rod readings which obtained when they were made.

Prof Le Conte has made a special study of hydraulics and is in charge of the work in hydrodynamics and higher hydraulics at the University of California, and is an authority on that subject.

Prof. Le Conte elected to make a series of experiments with models of the Niles and Sunol Dams. These models, together with the stream beds above them, were exact miniature counterparts of the structures as they existed during the times of stream flow obesrvations. Results obtained from these models were expanded by the laws of hydrodynamics to apply to the dams themselves, and discharge curves were computed therefrom which are true for these dams, under the method of measurement which obtained during the period of the records.

For ordinary and high-water flows the results obtained by Prof. Le Conte are much more reliable than those obtained without experimental data of this sort. For very low flow, published experimental data is available, upon which theoretical deductions may be made.

After Prof. Le Conte submitted his report there were made, under my direction, by T. W. Espy, several theoretical deductions by recognized weir and stream formulae of the discharge over Sunol Dam with the water at its highest recorded stage, which occurred in March, 1911, and of which the records are guides.

These theoretical solutions were made for a comparison with Prof. Le Conte's results and are incorporated in this appendix, together with Prof. Le Conte's report in full.

The following summary of the discharge of Alameda Creek at its highest gaged quantity, in March, 1911, shows a substantial check of the results obtained by Prof. Le Conte's experiment, indicating that, if anything, his results give smaller quantities than actually occurred:

	C. F. S.	M. G. D.
Le Conte	28,800	18,600
Kutter	30,900	19,900
Bligh	31,000	20,000
Molitor	26,700	17,300

METHOD OF TESTING MODELS OF THE SUNOL AND NILES DAMS

BY

PROF. J. N. LE CONTE.

Mr. F. C. Herrmann, Chief Engineer, Spring Valley Water Company, San Francisco, Cal.

San Francisco, Cal., June 22, 1912.

Sir—I submit the following report on the methods of testing the small models of the Sunol and Niles Dams, and on the method of applying the results of said tests to the large dams in place.

The object of the tests was to determine with such data as was obtainable the rate of flow over the large dams in terms of the gage readings, or in other words to determine an approximate rating curve for each of these dams. The dams are irregular in profile, causing the stream to assume different cross-sections at various heights. The location of the gages was not in midstream and beyond the influence of the surface curve, but in the case of the Sunol Dam was on the wingwall of the north bank, and in the case of the Niles on the upstream face of the intake tower. Both of these positions are well within the surface curve. Furthermore, at times of high and moderately high water the dams discharged against a submerged head, and no record has been kept of the amount of this submergence corresponding to different gage heads.

These various complex conditions make the computation of the discharge curve difficult, and therefore it was suggested that tests on models of these dams be made, and the results extended so as to apply to the large dams.

Conditions for Experiments.

The models were constructed of wood. The Sunol model was exactly 1/20 the size of the large dam in every dimension. The Niles was about 1/19 the size of the dam. The upstream channel was made of cross-section similar to the present cross-section of the stream bed above the large dams. This section may have been different at times of high water, but no better data are obtainable. The stakes and other bench marks from which gagings were made were located in their proper relative positions. In addition to this a hook gage reading to 0.001 of a foot was located in midstream 5 feet above the crest of the model, and the main upstream head was taken with this. A 2″ x 6″ timber was placed across the channel 5 feet downstream from the crest, and this furnished a bench mark from which the downstream head and hence the submergence could be measured. Baffle boards about 40 feet downstream served as a means of varying the submergence through any required range. The flow over the models was measured by means of two sharp-edged fully contracted weirs, the weir box being amply large to eliminate the effects of velocity of approach. The head on the weirs was taken on a standard hook gage reading to 0.001 of a foot.

The testing box was located on San Mateo Creek, and was fed by water from the flume leading from the first Pilarcitos tunnel. Main adjustment of the supply was effected by operating the gates at Lake Pilarcitos. Closer adjustment was obtained by wasting water above the weir box into San Mateo Creek.

Sunol Model Dam Experiments.

The test on the Sunol model was made on June 13, 1912. The hook gages were leveled with reference to the dam and weir crests with an engineer's level, and all bench marks leveled in a similar way. The Pilarcitos gate was opened about 3 feet, which corresponded on the model to high water. The hook gage on the weir was set and read. All baffle boards were removed so that the discharging vein made a clear overfall. The hook gage above the dam was set and read (h).

With an ordinary rule the position at the surface of the gaging point was then noted (g). Then the position of the drownstream surface was taken with a rule, giving the downstream head (h_1). Owing to the disturbed condition of this surface no more accurate method of measuring was necessary.

Allowing the same quantity to flow over the model, baffle boards were inserted below so as to raise the downstream surface, and the above described measurements were repeated. Then more baffles were put in, and so on till 5 to 7 complete sets of measurements had been made on one rate of flow, or till the ratio $\frac{h-h_1}{h}$ dropped to about 2/10 or less.

The waste gate above the weir box was then opened a small amount, allowing less water to pass over the weirs and to the model. After conditions became steady, the entire set of measurements was repeated, starting with a clear overfall. This method was followed till the quantity was reduced to as small an amount as the 30″ weirs could handle.

Niles Model Dam Experiments.

The test on the Niles model was made on June 16, 1912, and was identical with that made on the Sunol model, with the exception of the measurements at the gage points (g). In the latter instance five measurements were made at different points around the gate tower.

The discharge curves for the models were first computed. The flow over the sharp edged weirs were computed by means of the standard formula

$$Q = c\ 2/3\sqrt{2g}\ b\ h^{3/2}$$

the coefficient "c" being taken from Hamilton Smith's tables for contracted weirs.

For each complete set of measurements, that is, for each single value of Q, a curve was plotted showing the relation between $\frac{h-h_1}{h}$, which may be called the "submergence ratio," and h, the upstream center head. These curves are shown on plates C 1a, C 1b, C 1c for the Sunol model, and plates C 5a, C 5b and C 5c for the Niles model. One fact is clearly seen from this set of curves, namely, that "h" is constant, or is unaffected for all ratios of submersion down to about 6/10 or ½. It may be stated that the effect of back water down to ratios of submergence of ½ is so slight as to be practically negligible on both models. In these tests with a given upstream head h, the quantity flowing over is practically the same for a submersion ratio of ½ as it is for a free overfall. As the ratio $\frac{h-h_1}{h}$ is reduced below ½, the upstream head h begins to rise, at first slowly, and then more rapidly; the condition $\frac{h-h_1}{h}=0$ being manifestly impossible.

Next the discharge curves for the models were plotted. These are shown in plate C 2 for the Sunol, and plate C 6 for the Niles models. They give the discharge over the models in second feet in terms of the midstream hook gage head 5 feet upstream. The lowest curve is for a submersion ratio of 5/10, and this curve also corresponds to all larger ratios including free overfall. The next curve above is for a ratio of 4/10, etc. These are rating curves, exactly as measured, and bear no relation to any discharge formula. All effect sof velocity of approach and of variable cross-section of the escaping stream are included in them.

Application of Experimental Results.

So far the problem is merely one of measurement or calibration of the models. The extension of these results to the large dams, however, it is a matter of theoretical investigation purely. Apparently the required result can be obtained by the following method of procedure.

The point given by the great flood of 1911 can be located at A and B on a reduced scale of heads but for identical submersion on plates C 2 and C 6, and similar probable discharge curves for the models can be drawn. These would represent the discharge over the models if operating under a *varying* submersion in exactly the same way that the large dams operate. Then by the use of standard submerged weir formulae, the scale of these last curves can be extended to that of the large dam.

The standard formula for the free overfall is

$$Q = c\ b\ h^{3/2}.$$

If h_v is the head corresponding to the velocity head of approach

$$Q = cb\ [(h+h_v)3/2 - h_v^{3/2}].$$

For a submerged weir,

$$Q = c\,b\left[h_2^{1/2}\left(h - \frac{h_2}{3}\right)\right]$$

where h_2 is the difference in level between the upstream and downstream heads, or $h-h_1$.

Finally, if velocity of approach is taken into account,

$$Q = cb\ [(h+h_y)\ (h_2+h_v)^{1/2} - 1/3\ (h_2+h_v)^{3/2} - 2/3\ h_v^{3/2}]$$

Now, if a weir or dam is extended in linear dimensions n times in each direction

$$b' = nb,\quad h' = nh,\quad h_2' = nh_2,\ \text{and}\ h_v' = nh_v.$$

This latter, though slightly approximate, may be seen as follows: The flow over a dam varies as the 3/2 power of the head and directly as the breadth, or as the 5/2 power of the linear dimension n. But the cross-section of the channel varies as the square of n, hence the velocity of approach or $\frac{Q}{a}$ varies as $n^{5/2}/n^2=n^{1/2}$, and the square of the velocity of approach varies directly as n.

Hence, substituting in the above formula for the submerged weir, we have

$$Q'=cnb\ [n(h+h_v)n^{1/2}(h_2+h_v)^{1/2} - 1/3n^{3/2}(h_2+h_v)^{3/2}-2/3\ n^{3/2}h_v^{3/2}]=Q\ n^{5/2}.$$

Hence in order to exaggerate the probable discharge curve of the small dam to such a scale as to represent the flow over the large dam, we must multiply the heads h by n and the discharge Q by $n^{5/2}$.

In a dam like the Niles, we have two separate portions, a rectangular notch or series of notches in the middle, and two sloping sides which together form a triangular notch. The flow over such a combination will be

$$Q=c_1b_1h_x^{3/2}+c_2b_2h_y^{3/2}+ \text{— — —} +c_3kh_z^{5/2}$$

and since $b_1'=nb_1$; $b_2'=nb_2$; $h_x'=nh_x$; etc: $Q'=Qn^{5/2}$.

The same will be true if velocity of approach is taken into account. It will be observed that this method requires no knowledge of the coefficient "c." This is taken care of in the assumed discharge curves of the models on plates C 1 and C 5.

Now, in the case of the Sunol model n=20, $n^{5/2}$=1789. With this the discharge curve on plate C 4 is computed. In the case of the Niles dam n=19, $n^{5/2}$=1574. From these figures the discharge curve on plate 8 is plotted.

Finally for each hook gage reading on the model, we have a surface measurement corresponding to that of the main gage on the dam. The ratio of these two measurements is taken directly from plates C 1 and C 5, where the readings are plotted along the short cross curves. The discharge curves on plates C 4 and C 8 show the flow over the dams in terms of the gage heads. This final curve is the one which should be used in computing the flood discharge of the creek in years past.

Yours truly,

J. N. LE CONTE.

June 10, 1912.

S. P. Eastman, Esq., Manager,

San Francisco, Cal.

Dear Sir—Replying to your inquiry of Saturday, as to at what points the gagings of the overflow of the water at Sunol and Niles Dams were taken, will advise that at Sunol the gagings were taken from the top of the concrete at a point 4 feet north of the fish ladder. When the water surface was above the top of the concrete at this point, the gagings were taken from one of a series of stakes according to the stage of the water. These stakes were located as follows:

Stake No. 1—1 foot above top of concrete and 8 feet upstream.
Stake No. 2—2 feet above top of concrete and 12½ feet upstream.
Stake No. 3—3 feet above top of concrete and 17 feet upstream.
Stake No. 4—4 feet above top of concrete and 21½ feet upstream.
Stake No. 5—5 feet above top of concrete and 26 feet upstream.
Stake No. 6—6 feet above top of concrete and 30½ feet upstream.

For all depths of water above this last stake, measurements were taken from a point on the top of the concrete wingwall 8 feet upstream from the upstream face of the north end of the dam.

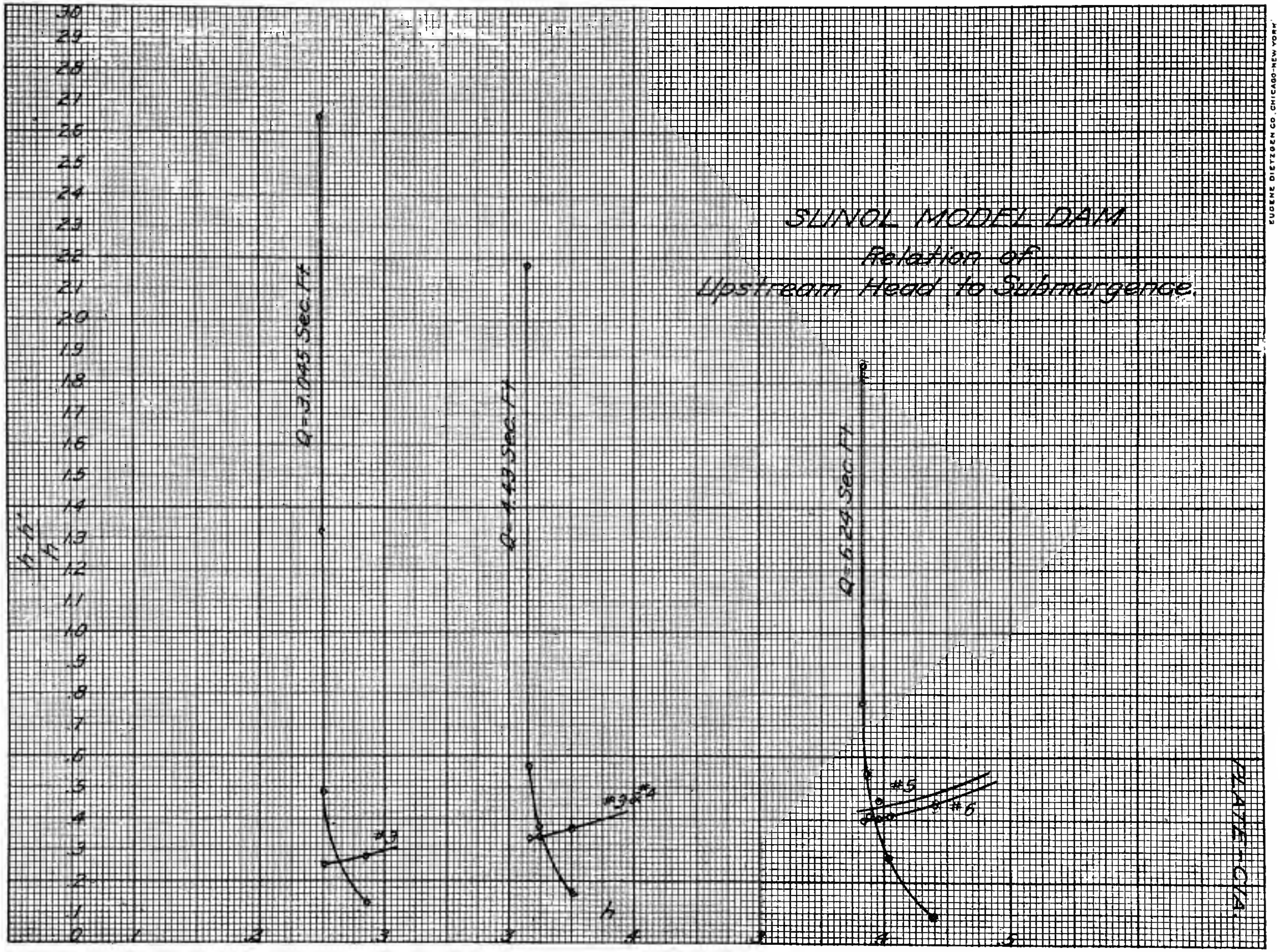
The gagings at the Niles Dam were taken from the top of the upstream face of the dam at a point about 4 feet north of the fish-ladder. When the water reached this height the gagings were taken from the top of the concrete 2 feet upstream from the inlet to the aqueduct. When the water reached this height the gagings were taken from a gage painted on the brickwork on the upstream face of the tower, allowances being made for the height caused by the current of the water striking the brickwork.

The information regarding the Niles Dam I have verified by old employes.

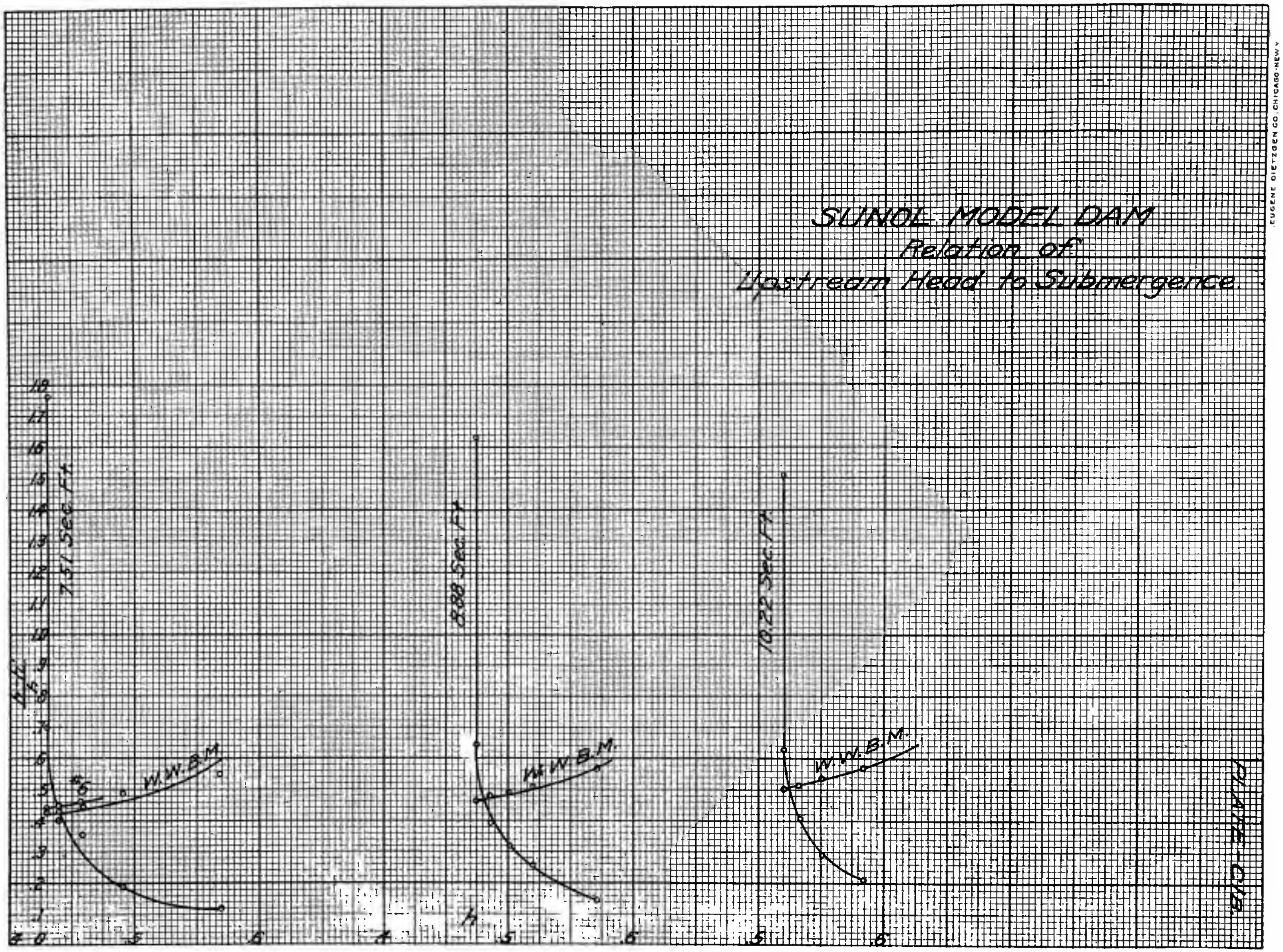
Very truly yours,

W. B. LAWRENCE,

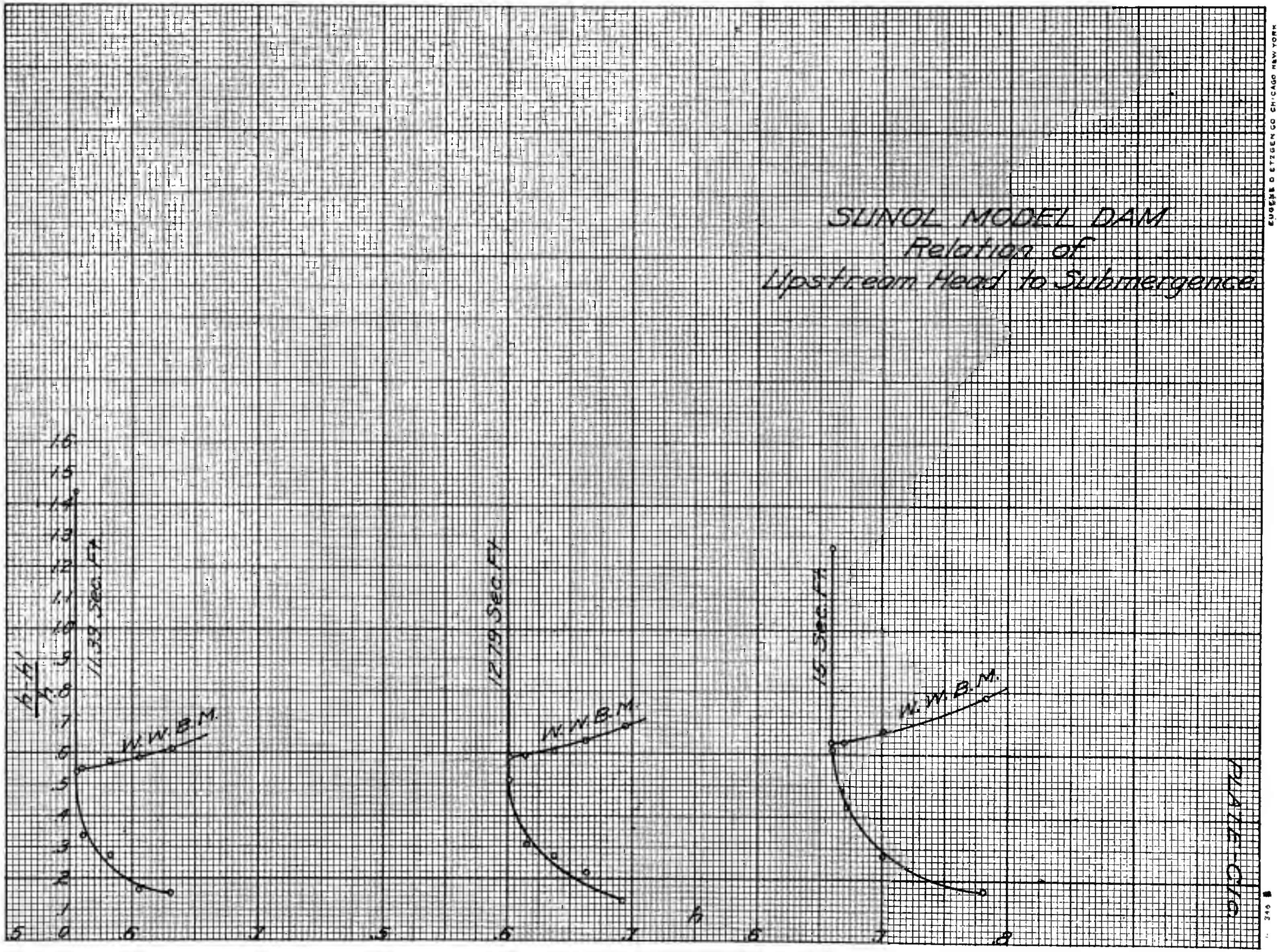
Superintendent Water Division, Spring Valley Water Company.



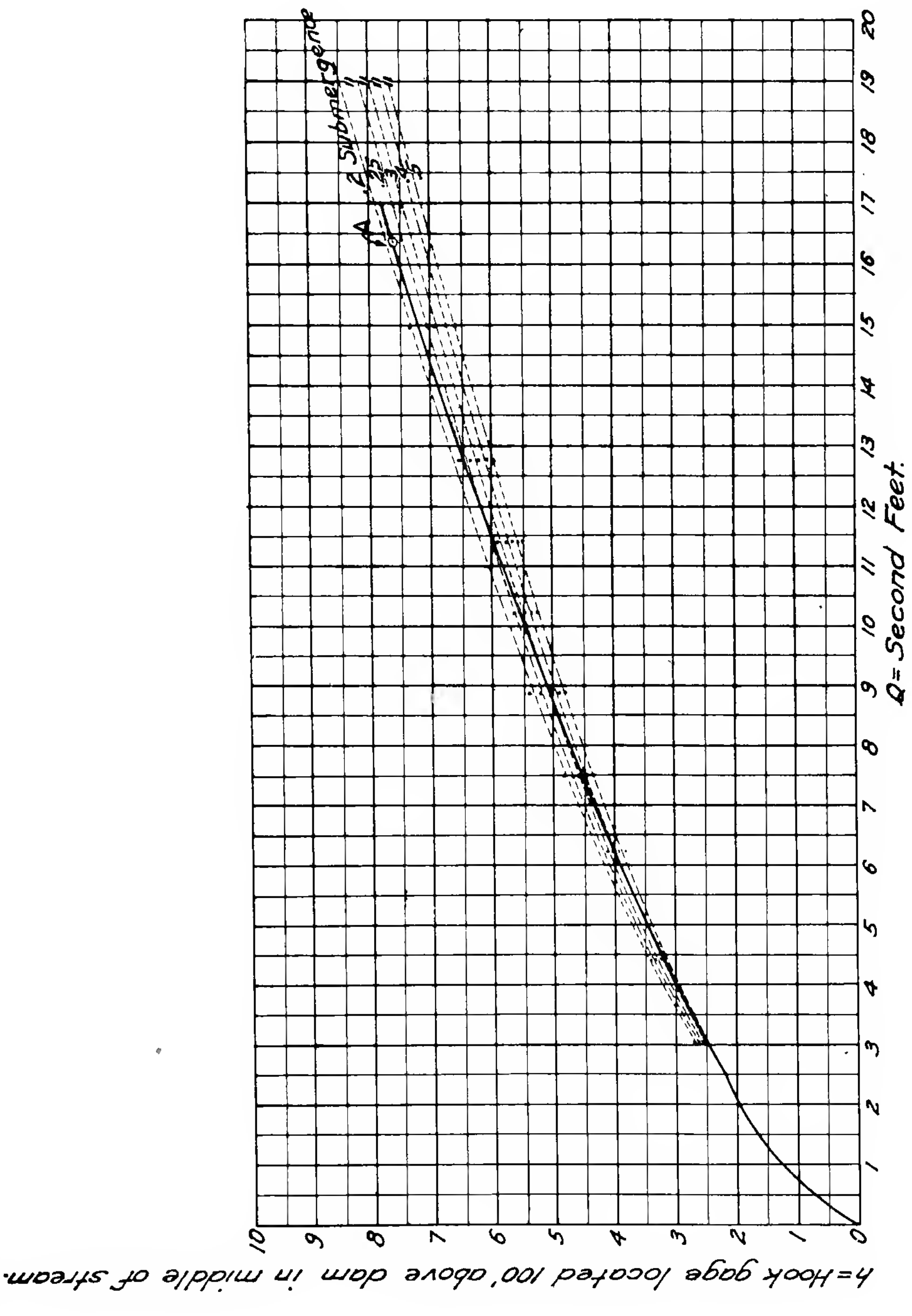
THESE RESULTS SHOW THE DROWNING EFFECT ON SUNOL DAM ONLY WHEN THE BACKWATER IS ABOUT TWO-THIRDS OF THE DEPTH OF WATER OVER THE DAM.



SUBMERGENCE AT SUNOL DAM MUST BE EXTREME BEFORE IT AFFECTS THE DISCHARGE OVER THE SUNOL DAM.

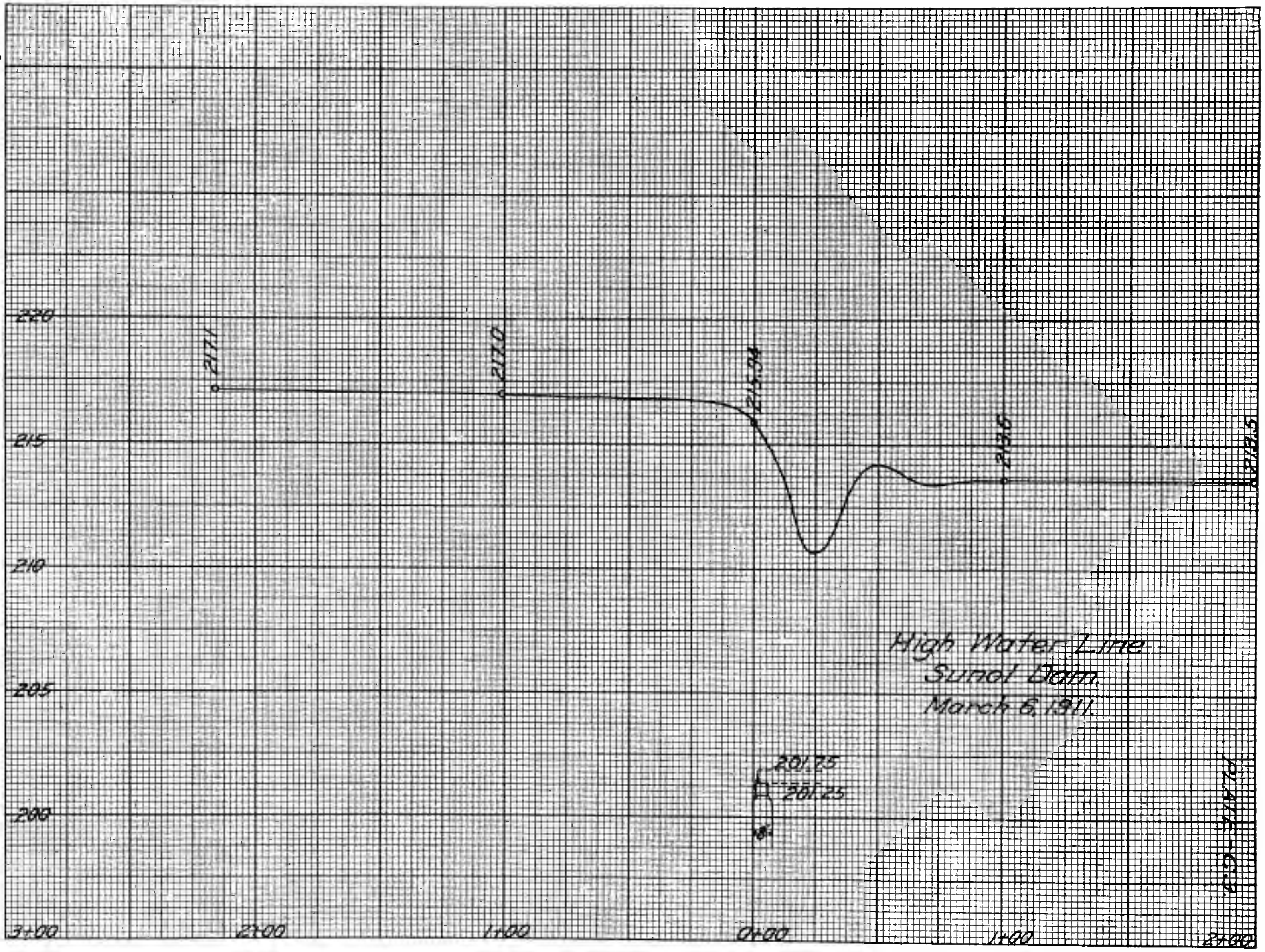


FURTHER EXPERIMENTS SHOW THAT SUBMERGENCE MUST BE VERY GREAT BEFORE IT AFFECTS THE FLOW OVER THE SUNOL DAM.

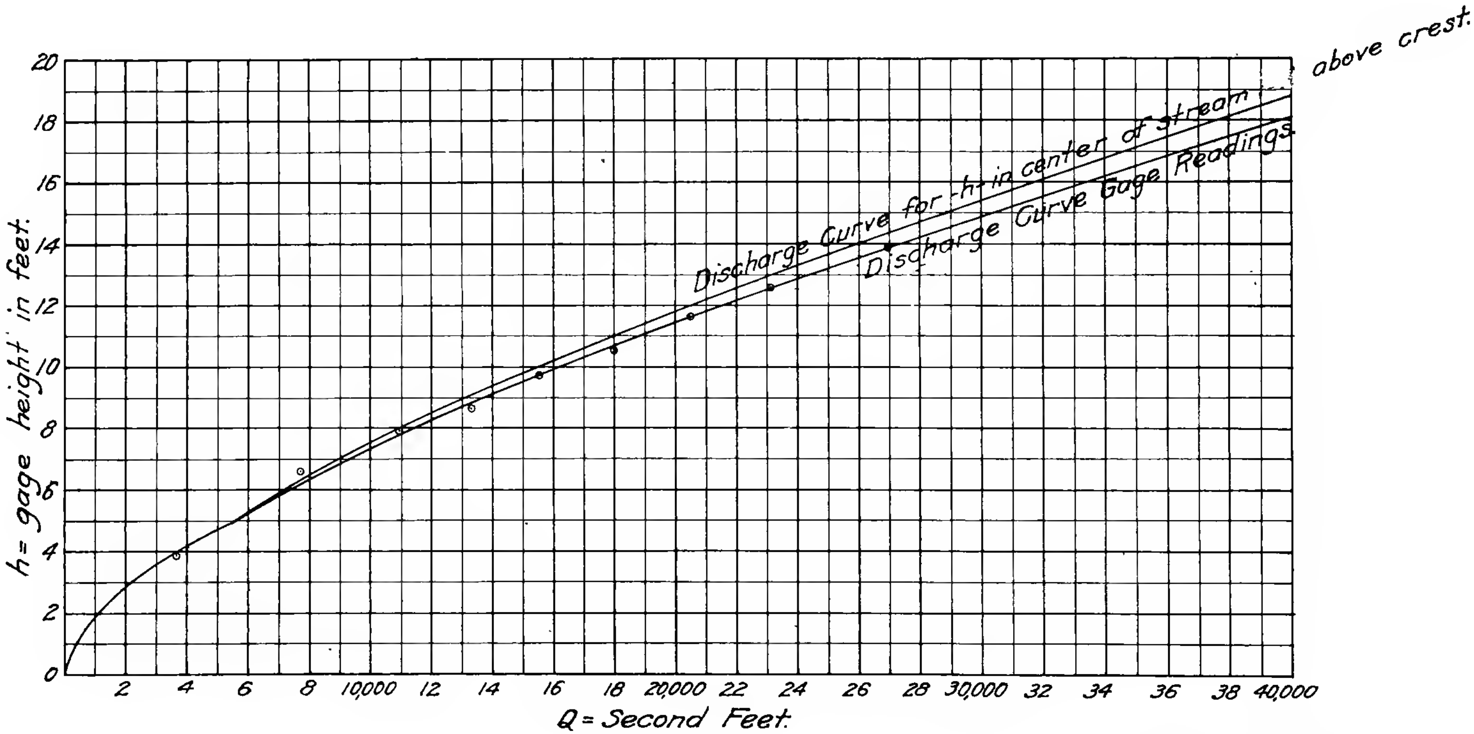


SUNOL MODEL DAM
DISCHARGE CURVE.

Plate-C-2



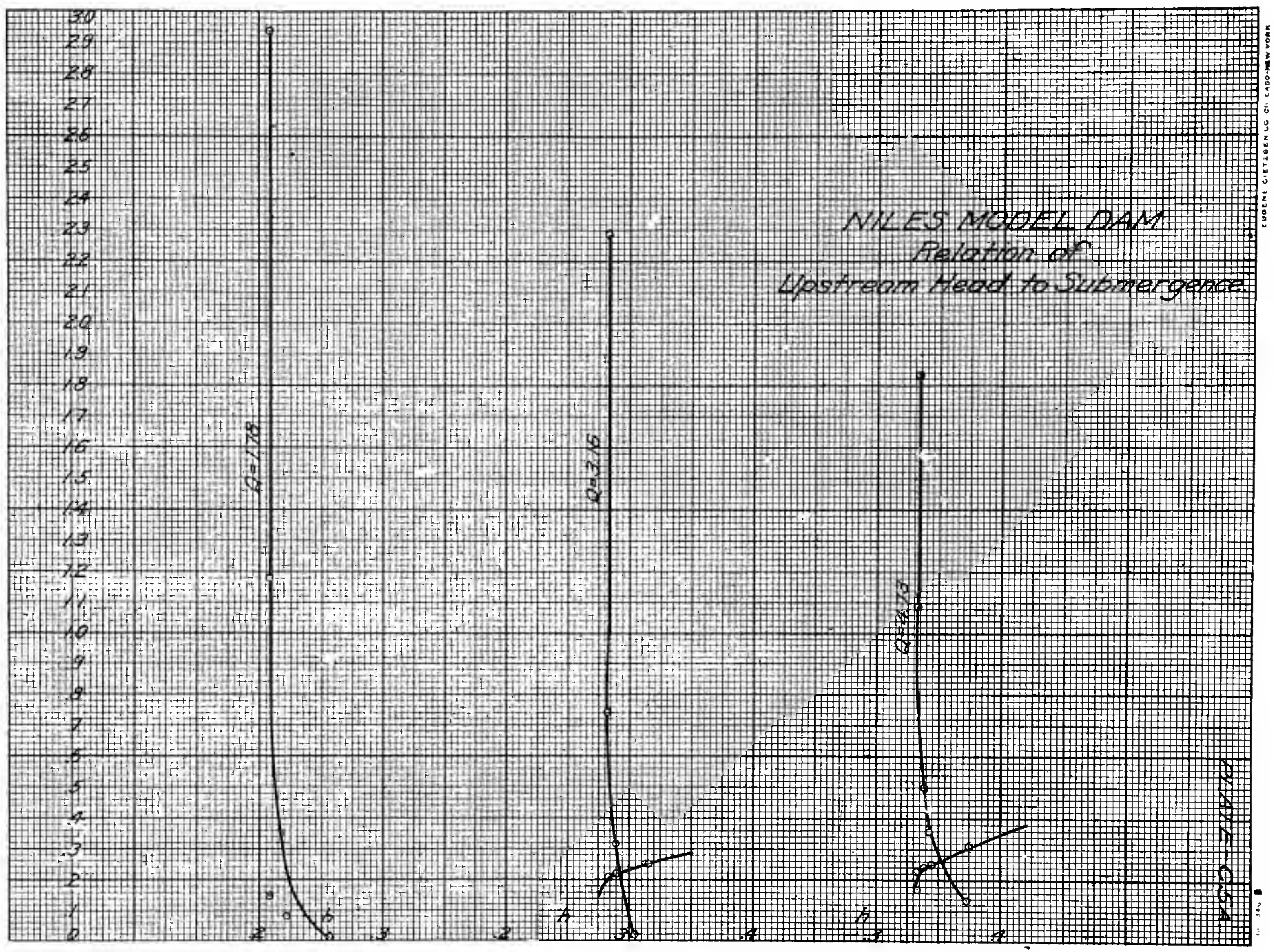
THE HIGH WATER LINE OF THE FLOOD OF MARCH, 1911, ABOVE AND BELOW SUNOL DAM WAS CAREFULLY SURVEYED.



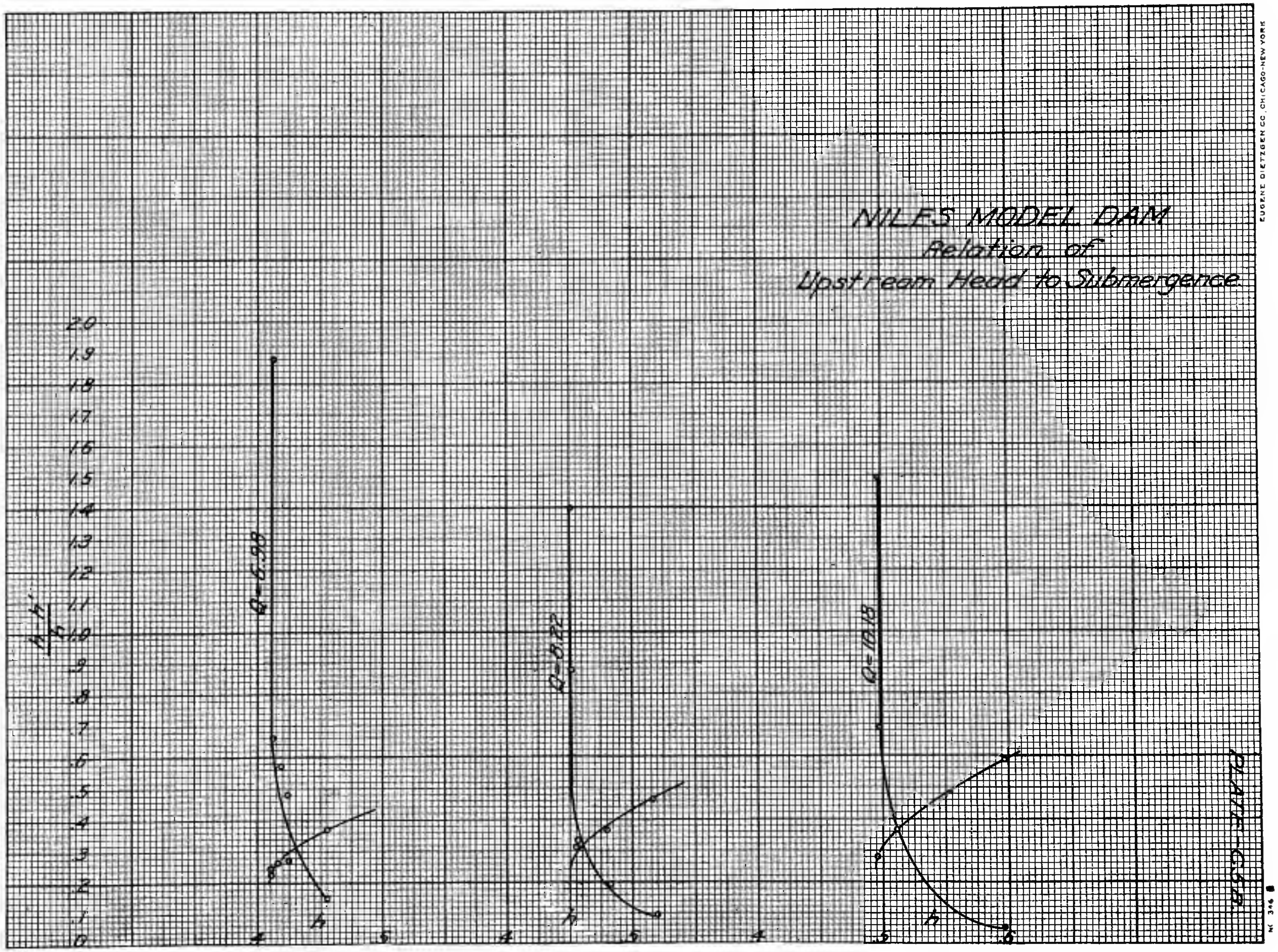
SUNOL DAM
DISCHARGE CURVE.

Plate - C-4

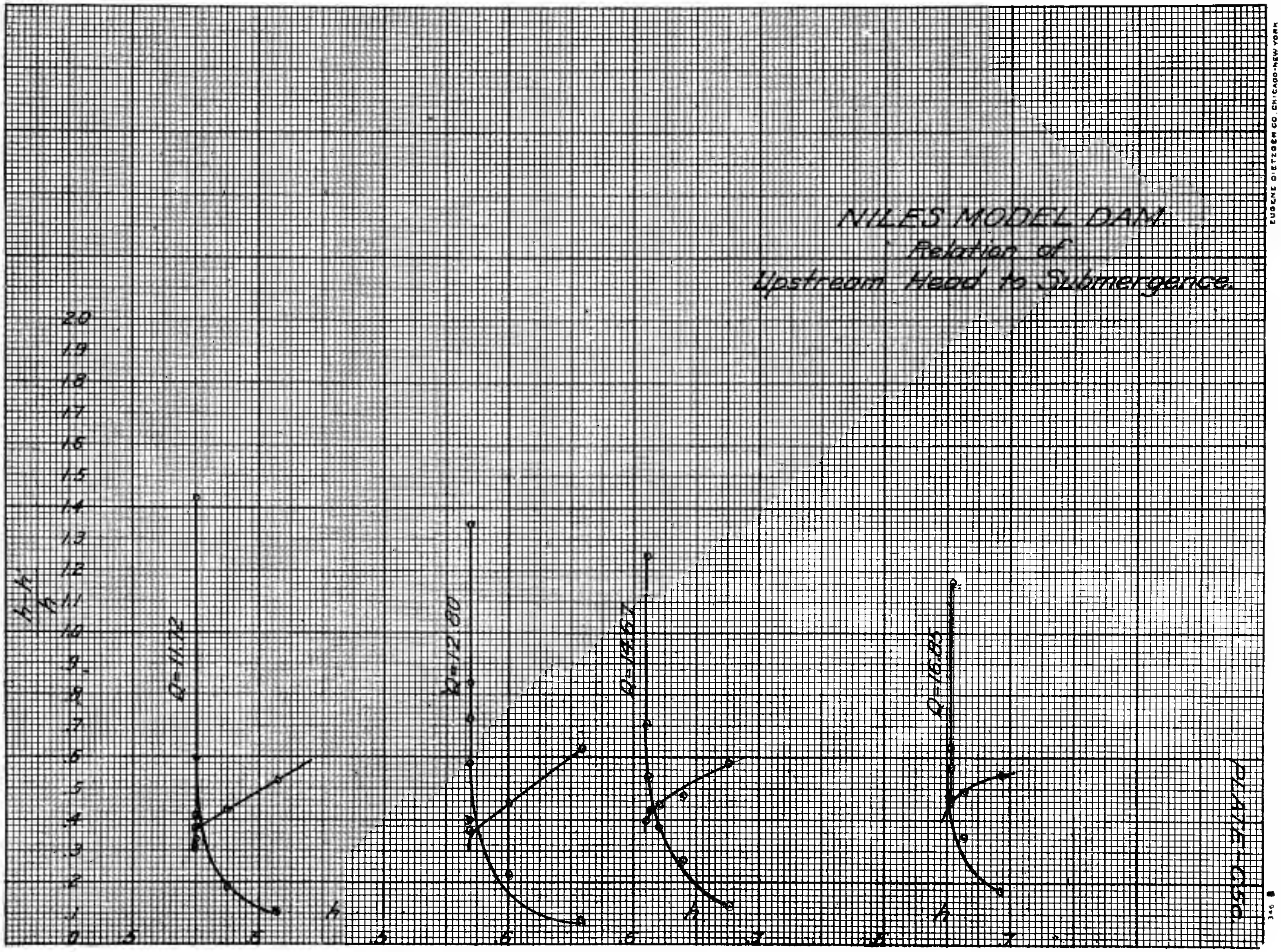
DISCHARGE CURVE FOR SUNOL DAM, PREPARED FROM EXTENSIVE EXPERIMENTS BY PROF. LE CONTE.



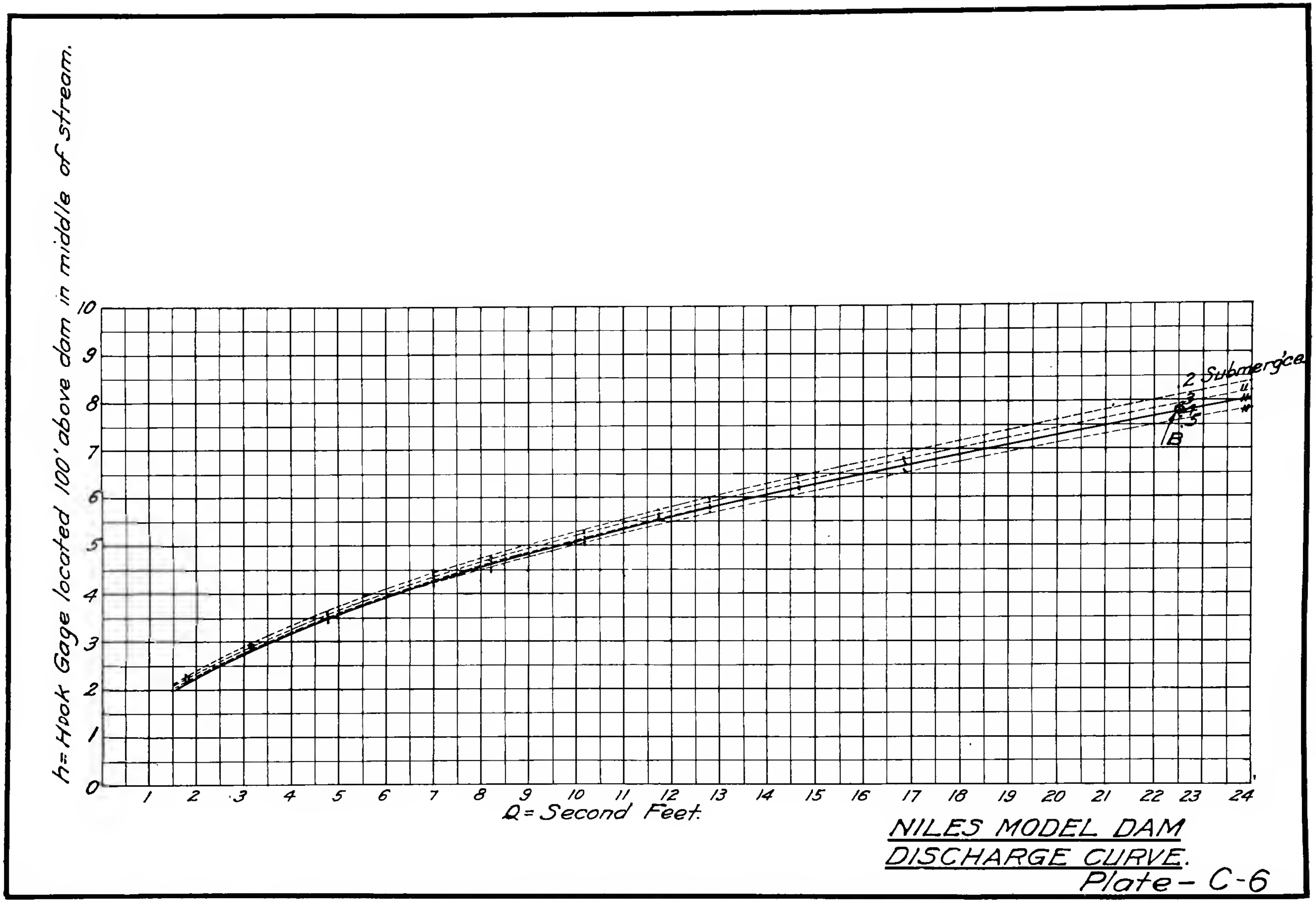
THE FLOW OVER NILES IS NOT AFFECTED BY SUBMERGENCE EXCEPT IN VERY HIGH WATER.



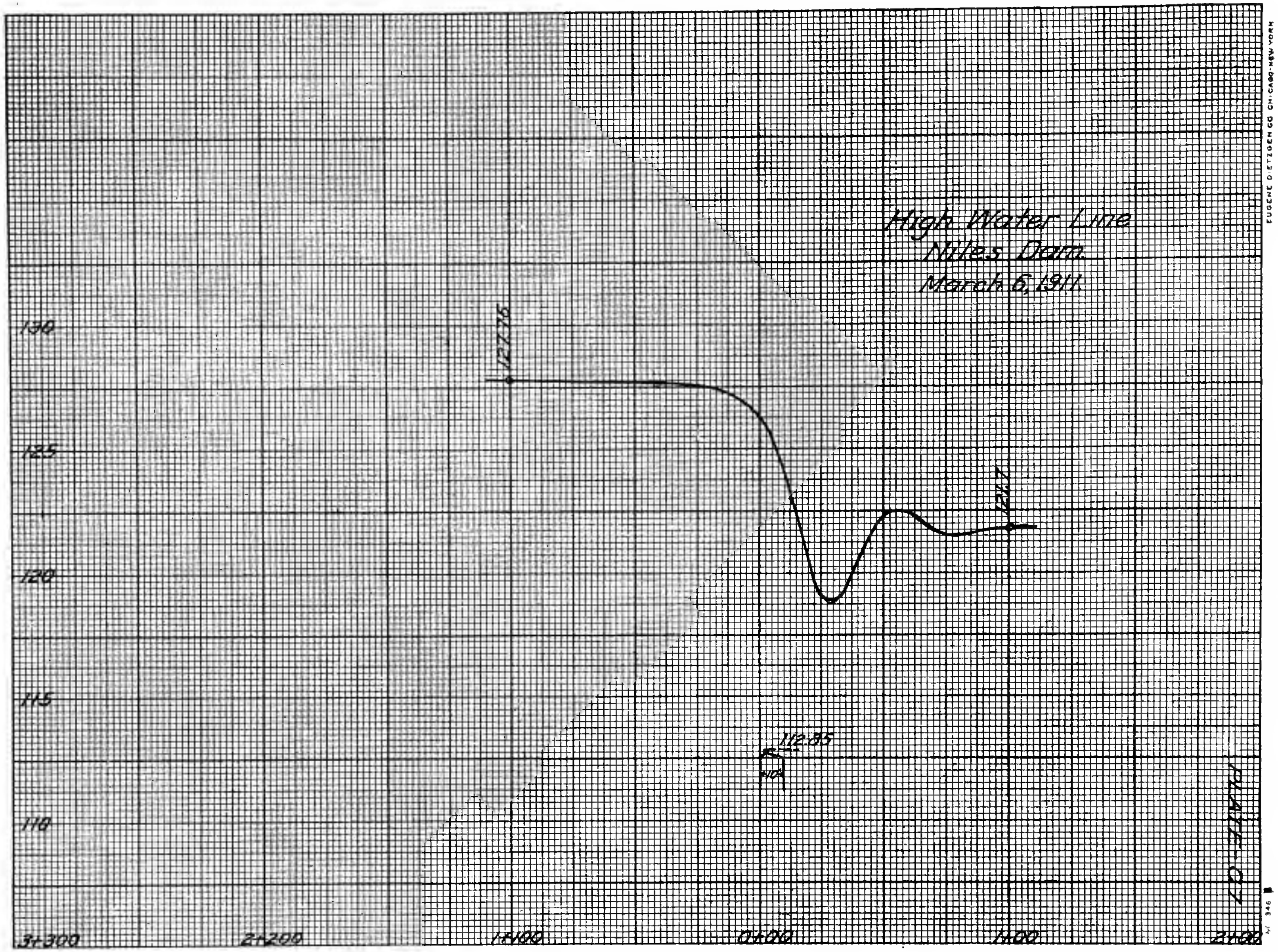
THESE RESULTS SHOW THAT DISCHARGE IS NOT AFFECTED UNLESS BACKWATER IS EXTREMELY HIGH.



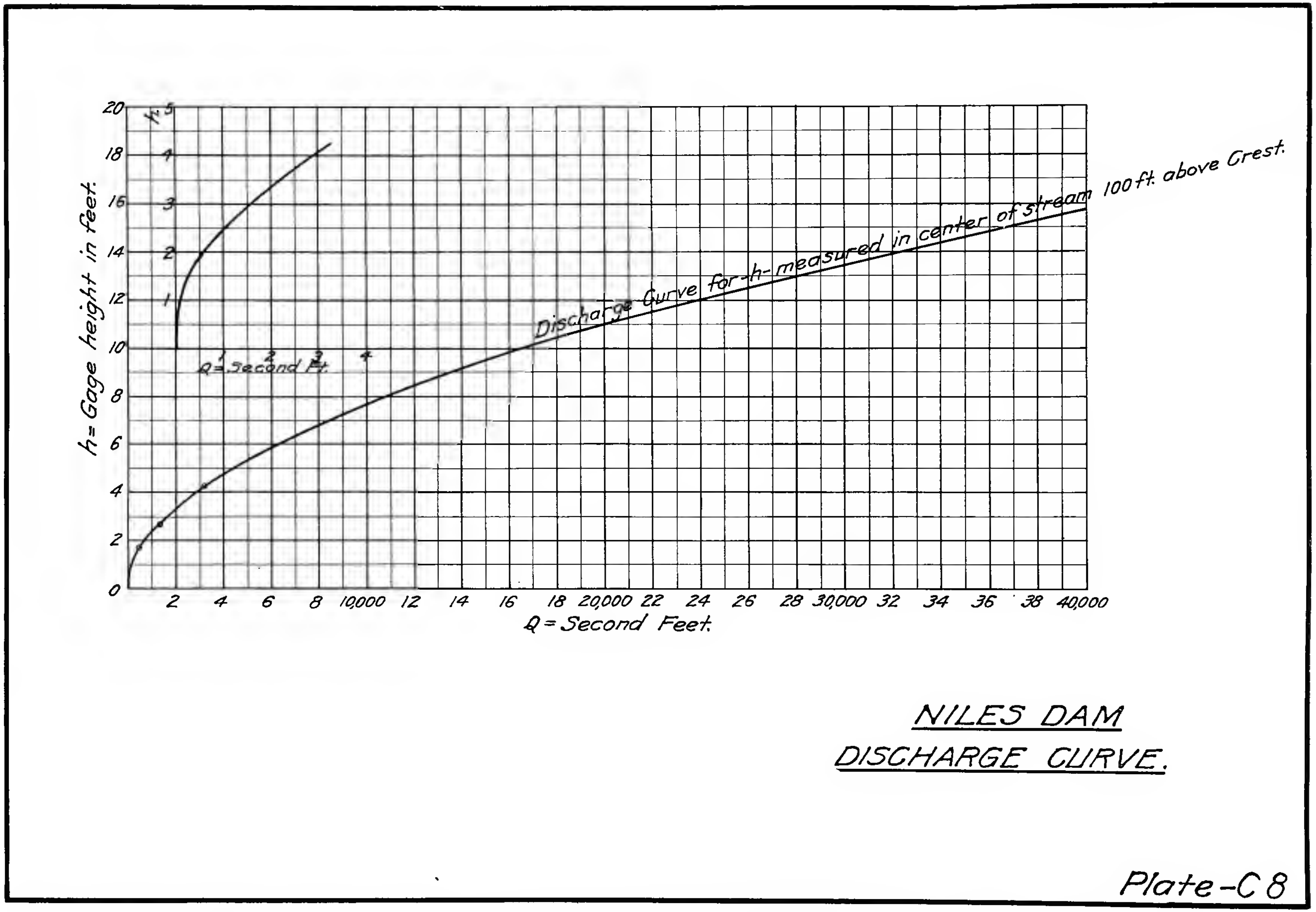
THE RESULTS SHOW THAT THE FRANCIS FORMULA CORRECTED FOR VELOCITY OF APPROACH IS ACCURATE EXCEPT WHEN BACKWATER IS APPROXIMATELY TWO-THIRDS OF THE HEAD.



DISCHARGE CURVE FOR MODEL OF NILES DAM, SHOWING EFFECT OF DIFFERENT DEGREES OF SUBMERGENCE. (LE CONTE.)



THE SHAPE OF STREAM SURFACE AT NILES DAM IN HIGH WATER OF MARCH, 1911.



PROF. LE CONTE DETERMINED THE DISCHARGE CURVE FOR NILES DAM FROM EXTENSIVE AND CAREFUL HYDRAULIC EXPERIMENTS. THE LOWER PART OF THE CURVE CHECK THE *ONLY* ACTUAL MEASUREMENTS MADE BY THE GOVERNMENT.

No.	Weir Hook	Dam Hook	Back Water	Position of Gage	Gage Reading	Weir Hook	Dam Hook	Q	h'	$\frac{h-h_1}{h}$	Gage Reading	
1	1.419	1.058	20 1/8	*1 Down	15/16	0.963	0.659	15.00	-0.172	1.261	0.639	
	1.419	1.058	15	"	15/16		0.659		+0.255	0.613	0.639	
	1.419	1.068	13 1/2	"	15/16		0.669		0.385	0.425	0.639	
	1.419	1.096	12	"	1/2		0.697		0.505	0.276	0.675	
	1.419	1.179	10 1/4	"	3/4" over top of forebay		0.780		0.654	0.1615	0.779	
2	1.320	0.999	20 3/4	#1 Down	1 5/8	0.864	0.600	12.79	-0.225	1.375	0.582	
	1.320	0.999	14 5/8	#1-Down	1 5/8		0.600		+0.287	0.519	0.582	
	1.320	1.016	13	"	1 7/16		0.617		0.422	0.316	0.597	
	1.320	1.035	12 1/2	"	1 1/4		0.636		0.465	0.269	0.613	
	1.320	1.063	11 3/4	"	13/16		0.664		0.525	0.209	0.649	
	1.320	1.092	10 3/4	"	3/8 –		0.693		0.609	0.121	0.686	
3	1.254	0.952	21	*1 Down	2 1/8	0.798	0.553	11.39	-0.245	1.443	0.540	
	1.254	0.952	15	"	2 1/8		0.553		+0.255	0.539	0.540	
	1.254	0.959	13 5/8	"	2 +		0.560		0.370	0.340	0.550	
	1.254	0.980	13	"	1 3/4		0.581		0.422	0.274	0.571	
	1.254	1.004	12	*1-Down	1 1/2		0.605		0.505	0.165	0.592	
	1.254	1.029	11 5/8	"	1 3/16		0.630		0.536	0.149	0.608	
4	1.197	0.918	21 1/4	*1-Down	2 9/16	0.741	0.519	10.22	-0.265	1.510	0.503	
	1.197	0.918	15 3/4	"	2 9/16		0.519		+0.193	0.628	0.503	
	1.197	0.932	14 1/4	"	2 3/8		0.533		0.318	0.404	0.519	
	1.197	0.947	13 3/8	"	2 3/16		0.548		0.391	0.287	0.535	
	1.197	0.981	12 1/2	"	1 3/4		0.582		0.464	0.206	0.571	
5	1.130	0.874	21 5/8	*1-Down	3 1/16	0.674	0.475	8.88	-0.298	1.627	0.462	
	1.130	0.874	16	"	3 1/16		0.475		+0.172	0.638	0.462	
	1.130	0.885	14 1/2	"	2 13/16		0.486		0.296	0.391	0.483	
	1.130	0.898	14	"	2 11/16		0.499		0.339	0.321	0.493	
	1.130	0.918	13 3/8	"	2 1/2		0.519		0.391	0.247	0.509	
	1.130	0.968	12 3/16	"	1 11/16		0.569		0.490	0.139	0.576	
6	1.058	0.829	22	* 6	1/4	0.602	0.430	7.51	-0.330	1.767	0.425	0.439
	1.058	0.829	15 7/8	*1-6 Down	3 1/2		0.430		+0.132	0.693	0.425	0.439
	1.058	0.839	14 7/8	*6 Down	-3 3/8		0.440		0.265	0.398	0.436	0.450
	1.058	0.856	14 1/2	*6 1 Down	3 3/4		0.457		0.297	0.350	0.446	0.460
	1.058	0.890	13 1/4	*1 Down	2 13/16		0.491		0.401	0.183	0.483	[illegible]
	1.058	0.969	12	"	1 15/16		0.570		0.505	0.114	0.555	
7	0.986	0.782	22	*5	1/8	0.530	0.383	6.24	-0.329	1.859	0.400	
	0.986	0.782	17	"	1/8		0.383		+0.089	0.768	0.400	
	0.986	0.785	16	"	0 –		0.386		0.172	0.555	0.410	
	0.986	0.793	15 1/2	*6	11/16		0.394		0.214	0.457	0.403	
	0.986	0.805	14 1/2	"	9/16		0.406		0.297	0.268	0.413	
	0.986	0.839	13 3/8	"	1/8		0.440		0.401	0.089	0.446	
8						0.419	0.316	4.43	-0.370	2.170	0.334	
							0.318		+0.140	0.560	0.334	
							0.323		0.203	0.371	0.339	
							0.353		0.297	0.1586	0.368	
9						0.325	0.249	3.045	-0.411	2.650	0.248	
							0.249		-0.079	1.317	0.248	
							0.249		-0.005	1.020	0.248	
							0.250		+0.130	0.480	0.248	
							0.283		+0.245	0.134	0.284	
10						0.226	0.183	1.795				
						0.105	0.086	0.577				

Zero reading on Dam Hook = .399 feet
Level on Dam Crest = 5.173
" " Timber 5 Ft. below = 3.668
" " " 15 " " = 3.652
Length of Crest 6'-9" + 9 5/8"
Zero of Hook Gage on Weir = .456

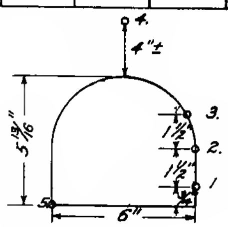
SUNOL DAM MODEL
RESULTS OF TESTS
JUNE. 13, 1912.

PLATE - C-9.

RESULTS OF PROF. LE CONTE'S EXPERIMENTS TO DETERMINE THE FLOW OVER SUNOL DAM.

No.	Weir Hook	Dam Hook	Back Water	#1	#2	#3	#4	#5	2-30" Weirs	Q	h	h_1	$\frac{h-h_1}{h}$	#4 above Crest
1	1.499	1.064	19	3 1/2	2	3/4	2	3 1/4	1.043	16.85	0.654	-0.114	1.174	0.461
	1.499	1.064	14 3/4	3 1/2	2	3/4	2	3 1/4			0.654	0.239	0.635	0.461
	1.499	1.064	14 1/4	3 1/2	2	3/4	2	3 1/4			0.654	0.282	0.569	0.461
	1.499	1.064	13 1/2	3 1/2	2	3/4	2	3 1/4			0.654	0.344	0.474	0.461
	1.499	1.074	12 3/8	3 1/4	1 3/4	3/8	1 9/16	2 1/2			0.664	0.438	0.341	0.498
	1.499	1.103	10 3/4	1 3/4	7/8	-1/4	15/16	1 7/8			0.693	0.573	0.173	0.550
2	1.405	1.020	19 1/2	4 3/8	3	1 3/8	2 3/4	3 7/8	0.949	14.67	0.610	-0.156	1.255	0.399
	1.405	1.020	15 1/2	4 3/8	3	1 3/8	2 3/4	3 7/8			0.610	0.177	0.710	0.399
	1.405	1.023	14 1/4	4 1/2	3 1/8	1 3/8	2 3/8	3 3/8			0.613	0.282	0.540	0.430
	1.405	1.030	13	4	2 7/8	1 1/8	2 1/4	3			0.620	0.386	0.377	0.441
	1.405	1.050	12	2 7/8	2	7/8	1 13/16	2 5/8			0.640	0.469	0.267	0.477
	1.405	1.087	10 1/2	1 1/4	1/2	-5/8	5/8	1 3/4			0.677	0.594	0.123	0.576
3	1.320	0.980	20	5	3 1/2	2	3 3/16	4	0.864	12.80	0.570	-0.197	1.346	0.362
	1.320	0.980	16 1/2	5	3 1/2	2	3 3/16	4			0.570	0.094	0.836	0.362
	1.320	0.980	15 3/4	5	3 1/2	2	3 3/16	4			0.570	0.157	0.725	0.362
	1.320	0.980	14 3/4	5	3 1/2	2	3 3/16	4			0.570	0.239	0.581	0.362
	1.320	0.980	13 1/2	4 3/4	3 1/4	1 7/8	2 3/4	3 3/8			0.570	0.344	0.397	0.399
	1.320	1.012	12	3 1/4	2 3/4	1 1/2	2 1/8	3			0.602	0.469	0.222	0.451
	1.320	1.070	10 1/4	1 3/8	3/4	-3/8	0	1			0.660	0.615	0.073	0.628
4	1.270	0.959	20 1/2	5 3/8	4	2 3/8	3 3/4	4 5/8	0.814	11.72	0.549	-0.240	1.436	0.316
	1.270	0.959	15	5 3/8	4	2 3/8	3 1/2	4 5/8			0.549	0.219	0.601	0.336
	1.270	0.960	13 3/4	5 1/8	4	2 5/8	3 1/16	3 3/4			0.550	0.323	0.413	0.373
	1.270	0.985	12	2 3/4	2 5/8	1 5/8	2 3/8	3 1/8			0.575	0.469	0.184	0.430
	1.270	1.024	11	1 1/2	1 1/2	3/4	1 1/4	1 3/4			0.614	0.552	0.101	0.524
5	1.195	0.905	20 1/2	6	4 3/8	3	4 3/16	5 1/8	0.739	10.18	0.495	-0.240	1.485	0.278
	1.195	0.905	15 3/4	6	4 3/8	3	4 3/16	5 1/8			0.495	0.157	0.683	0.278
	1.195	0.921	13	4	4	2 5/8	3	3 3/4			0.511	0.386	0.245	0.378
	1.195	1.008	10 3/4	1	1	5/8	1/2	1			0.597	0.573	0.040	0.586
6	1.095	0.859	21	7 1/8	5 3/8	4	4 1/2	5 7/8	0.639	8.22	0.449	-0.278	1.396	0.253
	1.095	0.859	17	7 1/8	5 3/8	4	4 1/2	5 7/8			0.449	0.055	0.878	0.253
	1.095	0.865	14	4 5/8	5	3 3/4	3 3/4	4 3/4			0.455	0.305	0.330	0.316
	1.095	0.891	13	3 1/4	3 5/8	3 1/8	3 1/16	3 5/8			0.481	0.389	0.191	0.373
	1.095	0.927	12	2 1/4	2 1/2	2 1/4	2	2 3/8			0.517	0.472	0.087	0.461
7	1.028	0.821	22	7 1/2	5 3/4	4 1/2	4 3/4	6 1/4	0.572	6.98	0.411	-0.361	1.880	0.230
	1.028	0.821	16	6 3/4	6 1/8	4 5/8	4 9/16	5 3/4			0.411	0.139	0.662	0.247
	1.028	0.827	15 1/2	5 3/4	6	4 7/16	4 3/8	5 1/2			0.417	0.180	0.568	0.263
	1.028	0.834	15	5	5 1/8	4 5/8	4 1/4	5 3/8			0.424	0.222	0.477	0.274
	1.028	0.864	13	3 1/4	3 3/8	3 3/8	3 1/8	3 3/8			0.454	0.389	0.143	0.368
8	0.894	0.743	21	9 1/2	7 1/4	6	5 1/2	7 3/8	0.438	4.73	0.333	-0.278	1.835	0.170
	0.894	0.743	18	7 7/8	7 3/4	6	4 3/4	6 5/8			0.333	-0.028	1.085	0.230
	0.894	0.750	15 5/8	5 1/2	5 7/8	5 1/2	4 11/16	6			0.340	0.170	0.500	0.237
	0.894	0.754	15	4 3/4	4 7/8	5	4 9/16	5			0.344	0.222	0.355	0.247
	0.894	0.764	13 3/4	3 3/4	3 7/8	4	3 7/8	3 7/8			0.374	0.326	0.128	0.304
9	0.803	0.693	22	11	11	6 7/8	5	6 3/8	0.347	3.16	0.283	-0.361	2.280	0.211
	0.803	0.693	16 3/4	6 3/4	7	6 1/2	5 1/16	6 1/2			0.283	+0.076	0.741	0.206
	0.803	0.700	15 1/4	5 3/8	5 3/8	5 1/2	4 15/16	5 3/8			0.290	0.201	0.307	0.216
	0.803	0.728	14	4 1/4	4 3/8	4 5/8	4 9/16	4 1/2			0.313	0.305	0.021	0.247
10	0.681	0.618	22 1/2				5 3/4	7	0.225	1.78	0.208	-0.403	2.938	0.149
	0.681	0.618	18 1/2				5 3/4	7			0.208	-0.038	1.183	0.149
	0.681	0.632	15 3/16								0.222	0.205	0.077	
	0.681	0.666	14 5/8								0.256	0.253	0.012	
11	0.580	0.543		3/16 down from top intake – Q = 0.752										
	0.557	0.494		13/16 " " " " – Q = 0.278										
	on one weir			Top of intake 1 1/8" above crest.										

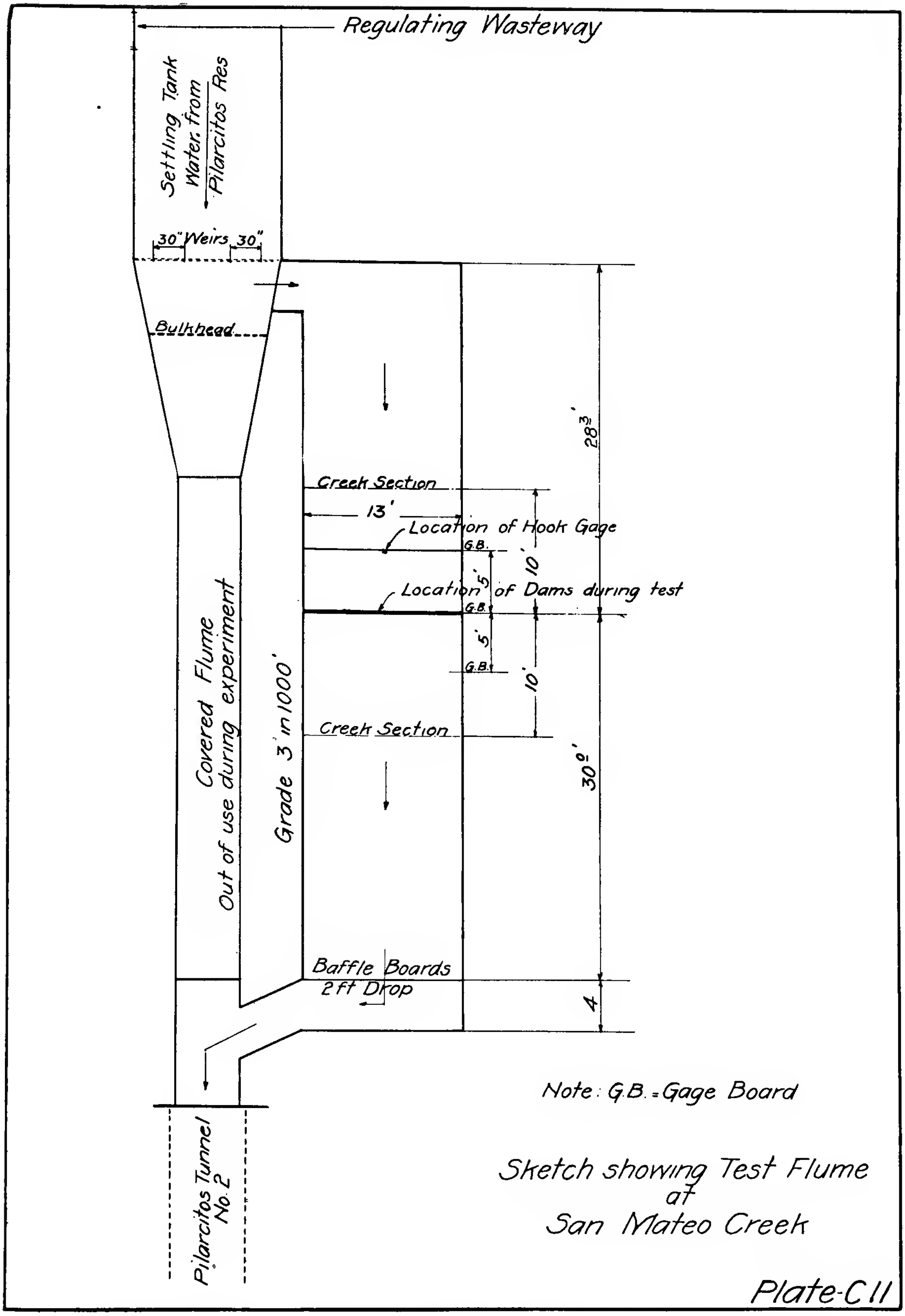
Zero reading on 30" weirs hook gauge = 0.456
" " " upstream " " = 0.410
Level rod readings:
On crest of dam at center = 5.215
Bench mark 5 feet down stream = 3.746
On top tower = 4.587
Elevation bench mark above crest = 1.469
Elevation top tower above crest = 0.628
For readings 6 to 10:
Level rod readings on crest = 5.220
" " " on bench mark 5 feet down stream = 3.748
Elevation of bench mark above crest = 1.472



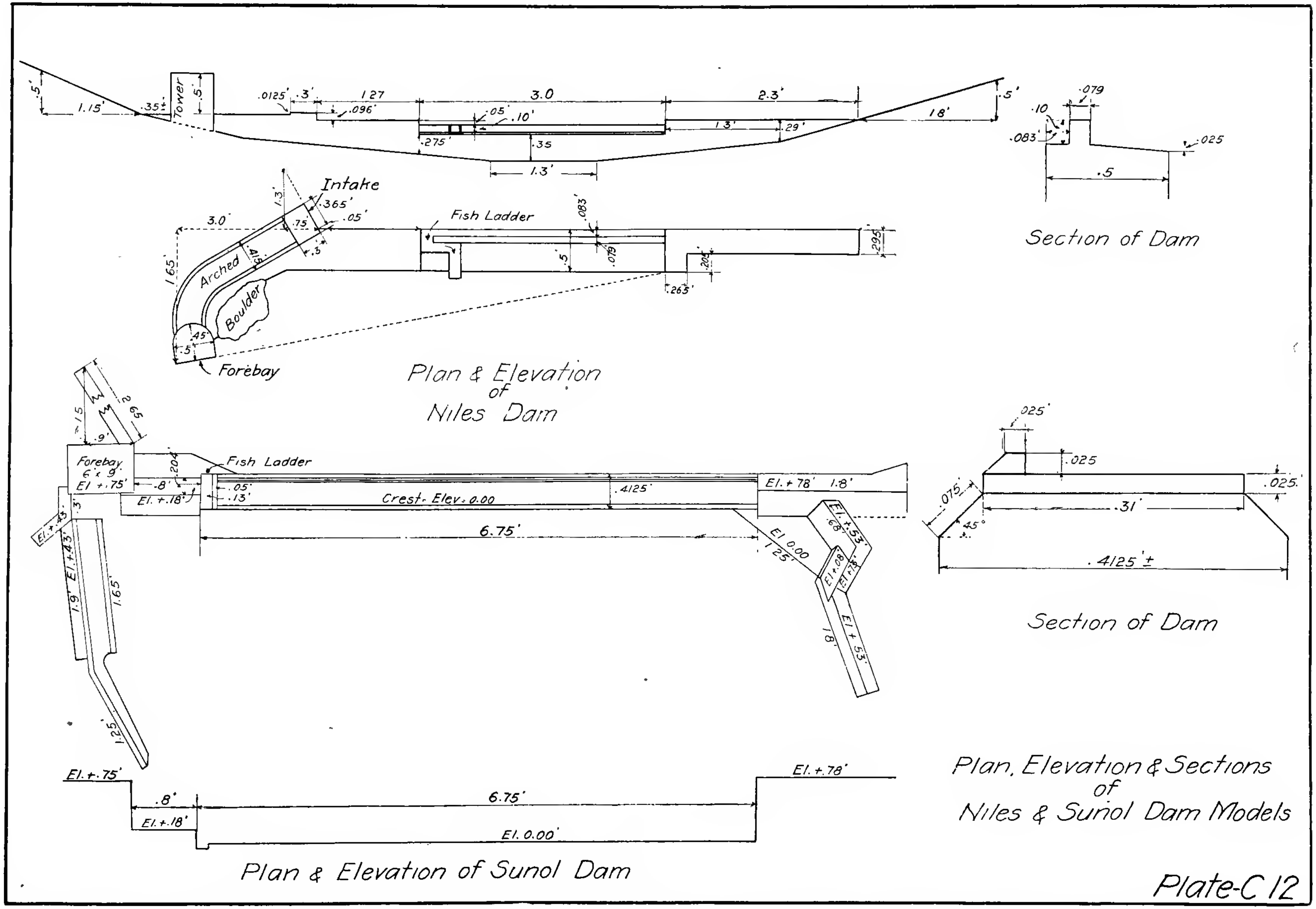
NILES DAM MODEL
RESULTS OF TESTS
JUNE. 16, 1912.

PLATE–C. 10.

RESULTS OF PROF. LE CONTE'S EXPERIMENTS TO DETERMINE THE FLOW OVER NILES DAM.



THE FACILITIES FOR PROF. LE CONTE'S EXPERIMENTS WERE IDEAL.



THE MODELS USED BY PROF. LE CONTE WERE EXACT COUNTERPARTS OF THE NILES AND SUNOL DAMS, THE APPROACHING STREAM BEDS BEING DUPLICATED FOR A DISTANCE PROPORTIONAL TO 200 FEET ABOVE DAMS.

THEORETICAL SOLUTIONS—DISCHARGE COMPUTED BY STREAM AND WEIR FORMULAE

BY

T. W. Espy,

Assistant Engineer, Spring Valley Water Company.

During the flood of March, 1911, gage height records kept at Sunol Dam show a depth of 14.1 feet as the maximum depth over the crest of the dam. A few days after the flood subsided a survey of the high water marks was made for a distance of over a mile upstream from Sunol Dam. A profile of this high water line for two thousand feet above Sunol Dam, together with a profile of the same high water below the dam, are shown on Plate C-13. On Plate C-14 are shown cross sections of the Alameda Creek channel at 200-foot intervals above and below Sunol Dam.

During this flood the waters overflowed the banks of the main stream channel and spread over the flat on the east side just above the dam. The banks on either side of the main channel are lined with a dense growth of trees and brush. This vegetation extends well down into the main portion of the channel, and at one time extended as far as the center, where the stumps may still be seen.

Kutter Formula.

In computing the maximum discharge of this flood by the Kutter formula, different portions of the cross section are governed by varying coefficients. After a careful inspection of the channel on the ground I have decided to divide it into three portions and compute each separately:

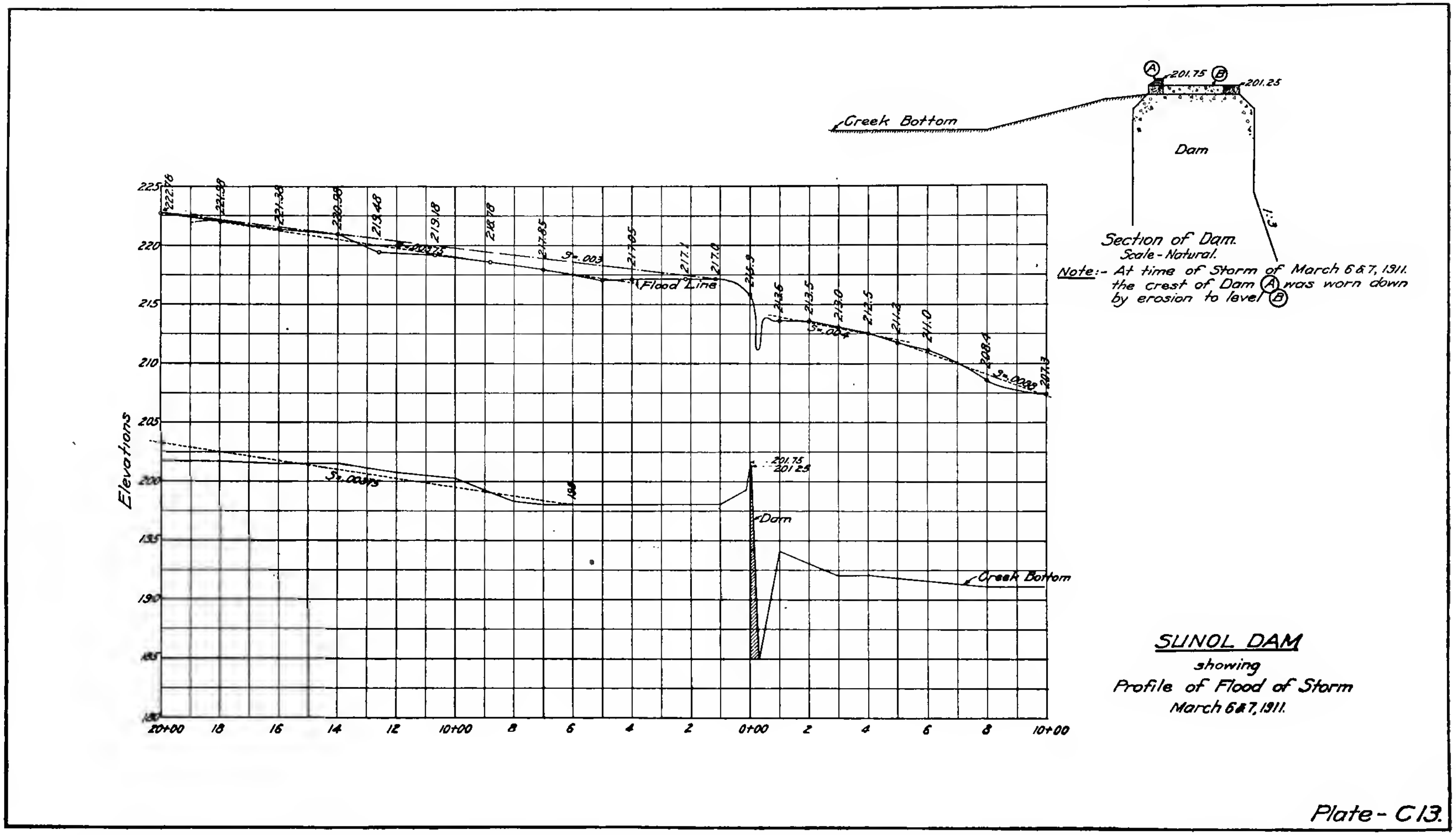
1. The area on either bank which is densly covered with trees, consisting of a strip extending from the foot of the bank slope back thirty feet on the east side and all the area above the foot on the bank slope on the west side. In computing the discharge for this portion I have assumed, on account of the obstruction of trees and vegetation, that only one-half the area was effective; and have used for the coefficient of roughness "n" a value of .045.

2. The portion overflowing the bank on the east side and beyond the dense tree area, I have computed with "n"=.040.

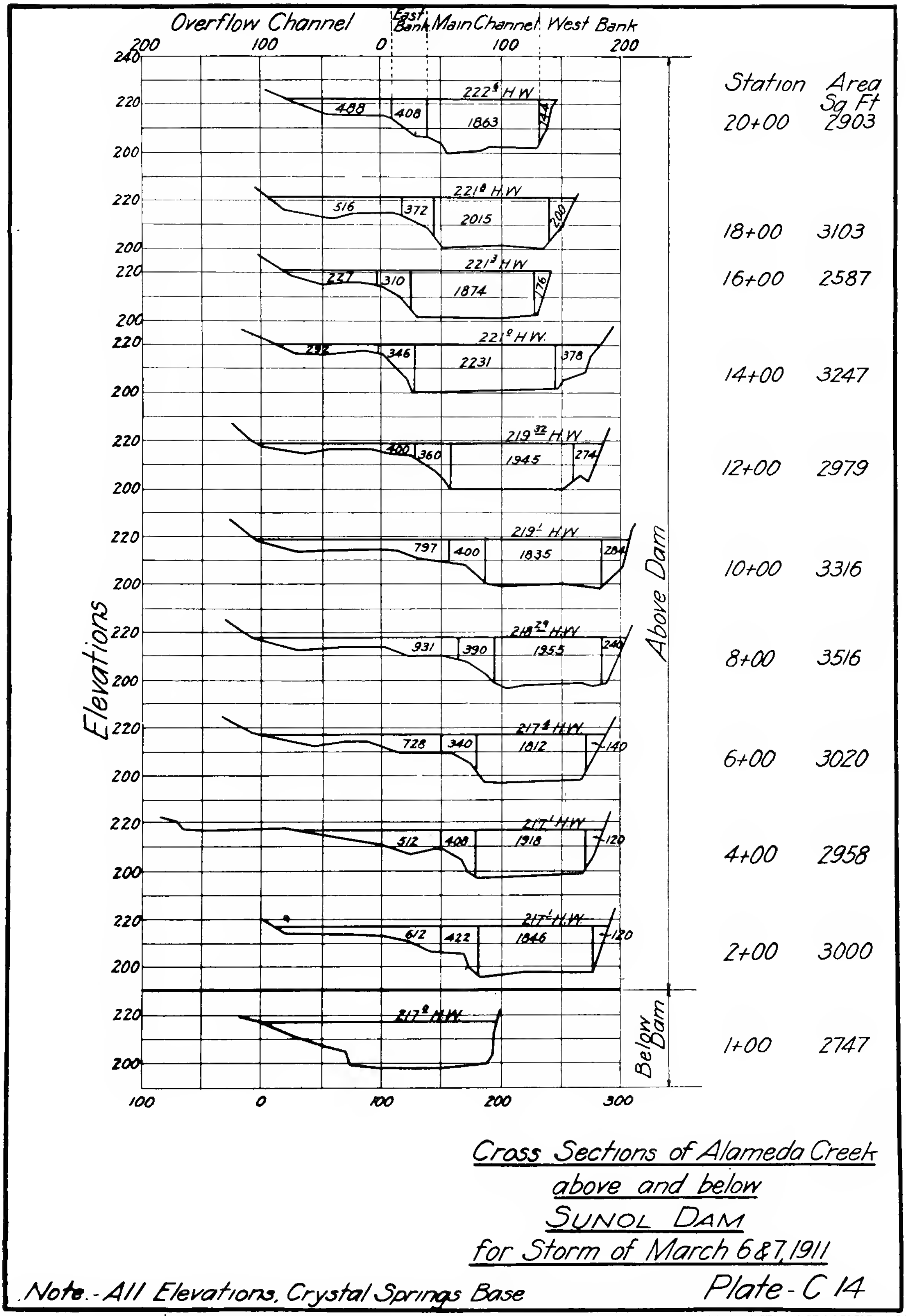
3. The remaining area or main channel I compute assuming "n"=.035.

The tabulation (Table C 15) shows subdivision of the ten cross sections from Station 20 above the dam. It also shows the wetted perimeter and mean hydraulic radius for each case. In determining the wetted perimeter it was assumed that each of the four sections was separated from the other by a wall.

The maximum discharge of the flood of March, 1911, when the water was 14.6 feet over the crest of Sunol Dam, computed by the Kutter formula as described above and tabulated (Table C 16), was 30,900 cubic feet per second.



FROM ACTUAL MEASUREMENTS OF WATER SLOPE IN MARCH, 1911, PROF. LE CONTE'S RESULTS ARE SUBSTANTIATED.



AT THE HIGH WATER OF MARCH, 1911, MANY CROSS-SECTIONS OF THE STRAIGHT CHANNEL OF ALAMEDA CREEK ABOVE SUNOL DAM WERE SURVEYED. COMPUTATION FROM THESE CHECK PROF. LE CONTE'S RESULTS.

Weir Formula.

By utilizing the discharge factors found above, we may compute the discharge by existing formulae applicable to submerged weirs of the type of Sunol Dam. The formulae which I have chosen are "Bligh's Formula" and the "Molitor Formula." It is not my purpose to discuss the merits of these formulae, but I take them as being perhaps a more thorough solution of the problem than some of the more simple formulae commonly used.

Bligh's Formula.

In his work entitled "The Practical Design of Irrigation Works," Mr. G. W. Bligh, M. Inst. C. E., formerly Executive Engineer of India P. W. Dept., in discussing weir formulae says (see page 122):

> "Fig. 4 represents a submerged or drowned weir. As in the case of a submerged orifice, the head "H" is the difference in level of the head and tail water, or the afflux. The depth of the film is termed as before, d, and that of the submerged portion of the film is (d-H)."
>
> "The passing film thus consists of two portions, the upper having a free overfall and

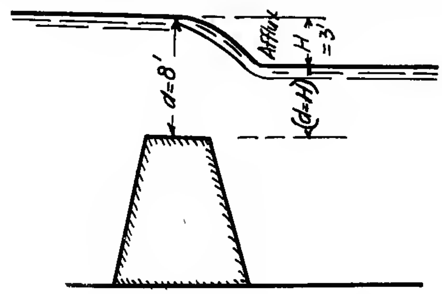


Fig. 4.

> the lower being what can possibly be considered as a submerged orifice, but without any top contraction. There can, likewise, be no bottom contraction or friction in the upper portion. Some authorities, as Jackson, cal-

TABLE C 15.

SUBDIVISION OF CROSS-SECTIONAL AREA OF ALAMEDA CREEK FLOOD WATERS ABOVE SUNOL IN MARCH, 1911.

Station.	Total area.	Area west bank covered with trees.	Area east bank covered with trees.	East and west banks covered with trees. One-half area.	W. P.	R.	Overflow channel. Area.	W. P.	R.	Main channel. Area.	W. P.	R.
20	2,903	144	408	276	105	2.63	488	100	4.88	1,863	130	14.3
18	3,103	200	372	286	106	2.70	516	120	4.30	2,015	128	15.7
16	2,587	176	310	243	96	2.53	227	86	2.64	1,874	138	13.6
14	3,247	378	346	362	118	3.07	292	92	3.17	2,231	155	14.4
12	2,979	274	360	317	110	2.88	400	133	3.00	1,945	138	14.1
10	3,316	284	400	342	106	3.23	797	172	4.64	1,835	138	13.3
8	3,516	240	390	315	111	2.83	931	176	5.30	1,955	128	15.2
6	3,020	140	340	240	92	2.61	728	162	4.50	1,812	126	14.4
4	2,958	120	408	264	103	2.56	512	162	3.16	1,918	130	14.7
2	3,000	120	422	271	104	2.60	612	148	4.13	1,846	136	13.6
..	....	....	....	2,916	....	27.66	5,503	...	39.72	19,294	...	143.3
..	....	....	....	292	....	2.77	550	...	3.97	1,929	...	14.3

Note.—One hundred foot stations with Station 0 + 00 at Sunol Dam.

TABLE C 16.

COMPUTATION BY KUTTER'S FORMULA OF MAXIMUM FLOW OF ALAMEDA CREEK ABOVE SUNOL DAM IN MARCH, 1911.

Obstructed channel.	Overflow channel.	Main Channel.
½ area=292 sq. ft.	Area=550 sq. ft.	Area=1929 sq. ft.
$R=2.77$; $\sqrt{R}=1.66$;	$R=3.97$; $\sqrt{R}=1.99$;	$R=14.3$; $\sqrt{R}=3.78$;
$S=0.003$; $\sqrt{S}=0.0548$;	$S=0.003$; $\sqrt{S}=0.0548$;	$S=0.003$; $\sqrt{S}=0.0548$;
$n=0.045$; $c=38.8$;	$n=0.040$; $c=47.4$;	$n=0.035$; $c=67.6$;
$V=c\sqrt{RS}=3.53$ ft. per sec.	$V=c\sqrt{RS}=5.17$ per sec.	$V=c\sqrt{RS}=14$ ft. per sec.
$Q=AV=1{,}031$ cu. ft. per sec.	$Q=AV=2{,}843$ cu. ft. per sec.	$Q=AV=27{,}006$ cu. ft. per sec.

Total discharge equals 30,880 cu. ft. per sec.

culate the discharge of each portion with two separate values of c, the upper by formula (8), and the lower by formula (2) or (3).

. . .

"It is clear, however, that the coefficient for the whole film must be a varying one, and the variation must be as "H" to "d". When "H" is very small in proportion to "d", the value of the coefficient will approach unity. This principle has been recognized in the "Madras Manual of Irrigation", where the solution of this difficult question of the single varying coefficient has been attempted. The matter has, however, quite recently been placed on a more satisfactory basis by the results of experiments lately made in Upper India on actual works. These proved the important fact that in submerged fall when the ratio of H:d : :1:3, then the discharge is practically identical with that of a free overfall; and when this proportion is exceeded, then only the discharge begins to be subject to the conditions prevailing in a submerged fall. This apparent paradox is due in part to the depression, or trough caused by the falling water in the tail pond, which neutralizes the back pressure at the tail water. On these premises the coefficient can be estimated with some degree of certitude, as it lies between two known values."

The formula that Bligh refers to as No. 8 is commonly known as "Francis Formula." Formulae (2) and (3) are also the commonly used formulae for submerged orifices.

Mr. Bligh presents the following formula for solving the discharge over submerged weirs where the back water is more than two-thirds the total height of the water over the weir crest (Bligh, page 123):

$$Q = cl[\sqrt{2\ gH} \text{ x } 1/3(3d\text{-}H)] \qquad (10)$$

where

Q=discharge in cubic feet per second

l=length of crest

d=depth of water over crest or head

H=difference in elevation of back water and water over crest

c=emperical coefficient varying between

$.8095$, when $\dfrac{d}{H} = 3$, and 1.00, when $\dfrac{d}{H} = 100$.

The above formula is for discharge where there is no velocity of approach. Where there is velocity head to be considered, Bligh uses a second coefficient or multiplicand obtained by the formula:

$$c_1 = c\ (1 + \frac{h}{3H})^{3/2} - (\frac{h}{3H})^{3/2} \qquad (9)$$

as modified to fit our conditions.

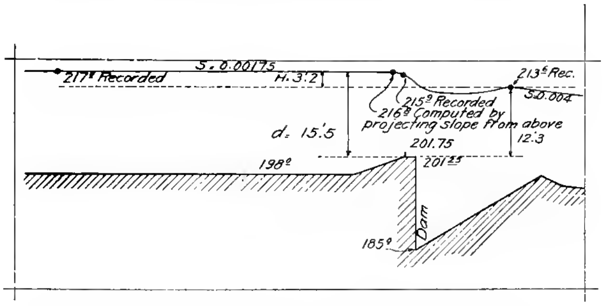
h=head due to velocity of approach=.0155 v^2

H and c=same as in above formula (10).

One hundred thirty-five feet of the weir crest of Sunol Dam is at elevation 201.25, and 16 feet at elevation 204.90. Dividing the weir into two sections and solving as two separate weirs, we have for one portion:

H=3.2 ft.; d=15.5 ft.; c=.814; 1=135 ft.; and in the second section of the weir we have

H=3.2 ft.; d=11.8 ft.; c=.811; 1=16 ft.



Substituting in Bligh's formula we have:

$Q_1 = .814 \times 135\ [8.02 \times 1.79 \times 1/3\ (3 \times 15.5 - 3.2)] = 22{,}800$ cubic feet per second for the discharge over the 135-foot section, and

$Q_2 = .811 \times 16\ [8.02 \times 1.79 \times 1/3\ (3 \times 11.8 - 3.2)] = 2{,}000$ cubic feet per second for the 16-foot section, making a total of 24,800 cubic feet per second, not taking into account any velocity of approach.

Substituting our values and solving Bligh's formula for the effect of velocity of approach, we have

$h = .0155\ V^2 = .0155\ (12)^2 = 2.23.$

$$(1 + \frac{h}{3H})^{3/2} - (\frac{h}{3H})^{3/2}$$

$$= (1 + \frac{2.23}{9.6})^{3/2} - (\frac{2.23}{9.6})^{3/2} = 1.25.$$

$24{,}800 \times 1.25 = 31{,}000$ cubic feet per second as the discharge over the dam, with a depth over the crest of 14.6 feet.

Molitor Formula.

David A. Molitor, C. E., in his "Derivation of new and mòre accurate formulas for the discharge through rivers and canals obstructed by weirs, sluices, etc., according to the principles of Gustav von Wex" and published in his work entitled, "Hydraulics of Rivers, Weirs and Sluices," establishes the following formulae for the solution of discharge over incomplete overfall weirs (see page 130, Molitor Hydraulic's):

$$Q = 2/3b\sqrt{2g}\left[u\,(S_1^{3/2} - S^{3/2}) + u_1\,\left(H_1 - \frac{nV^2}{2g}\right)\left(\frac{S_2^{3/2} - S_1^{3/2}}{S_2 - S_1}\right)\right]$$

where

$$S = \frac{v^2}{2g}\left[1 + \frac{B\text{-}b}{b}\cos^2\frac{\emptyset}{2}\right];\quad S_1 = S + H_2 + \frac{nV^2}{2g};$$

$$S_2 = S_1 + \frac{2v^2BK\cos^2\dfrac{\psi}{2}}{bg\left(H_1 - \dfrac{nV^2}{2g}\right)};$$

$$2/3u = .4001 + \frac{.00799}{H_2} + .000146b;$$

$$u_1 = .5346 + .000146b;$$

in which

S=pressure along surface filament.

S_1=pressure at depth H_2, or at surface of back water.

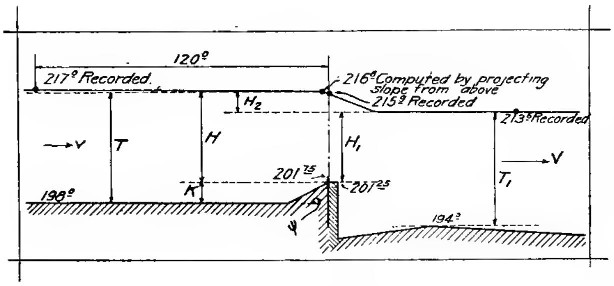
S_2=pressure along the filament at weir crest.

b=width of weir; n=.67;

u and u_1=coefficients of flow.

$\emptyset$=angle wing wall makes with direction of flow.

ψ=angle upstream face makes with direction of flow, and the figure below shows the other factors:



To compute the discharge over Sunol Dam these formulae must be modified somewhat, as our wing walls are at different angles and the velocity of water striking these wing walls is much less than the velocity of approach over the main dam. Being guided by results obtained by Kutter's formula we assume a velocity of 12 feet in front of the weir as in the solution of Bligh's formula, and a velocity of 5 feet per second striking the wing walls.

Then

$$S = \frac{v^2}{2g}\left[1 + \left(\frac{B\text{-}b}{b}\right)\cos^2\frac{\emptyset}{2}\right]$$

becomes

$$S = \frac{v^2}{2g} + \frac{v_1^2}{4g}\left[\frac{B\text{-}b}{b}\cos^2\frac{\emptyset_1}{2} + \frac{B\text{-}b}{b}\cos^2\frac{\emptyset_2}{2}\right].$$

Assuming discharge=30,500

Area 100 ft. above dam=2747; then $v = \frac{30,500}{2747}$ =11 ft.

But as the dam lies directly in front of the main portion of the stream channel which we found by Kutter's formula to have velocity of 14 feet, we are justified in increasing "v" to at least 12 feet per second.

Area 100 ft. below dam=3399; then $V = \frac{30,500}{3399} = 9$ ft.

From diagram

T=18.8 ft.; T_1=19.6; H=15.5; H_1=12.3; H_2=3.2.

Assume

ψ=20°; K=3 ft.; B-b=24 ft.; $\emptyset$ on one side =90°; $\emptyset_2$ on other side=45°.

Substituting the proper values in these equations, we have:

$$S = \frac{12^2}{64.5} + \frac{5^2}{129}\left[\frac{24}{151}\cos^2\frac{90^0}{2} + \frac{24}{151}\cos^2\frac{45^0}{2}\right] = 2.27;$$

$$S_1 = S + H_2 + \frac{nV^2}{2g} = 2.27 + 3.2 + 0.67\,\frac{9^2}{64.5} = 6.31;$$

$$S_2 = S_1 + \frac{2v^2\,BK\cos^2\dfrac{\psi}{2}}{bg\left(H_1 - \dfrac{nV^2}{2g}\right)}$$

At Sunol Dam "B" in this equation equal "b," then substituting we have:

$$S_2=6.31+\frac{2\,(12)^2\times151\times3\cos^2\frac{20^0}{2}}{151\times32.2\,(12.3-\frac{.67\times9^2}{64.5})}=8.58;$$

$$2/3u=0.4001+\frac{0.00799}{3.2}+0.000146\times151=.4228;\ u=0.635;\ u_1=0.5346+0.000146b=.556;$$

$$Q=2/3b\sqrt{2g}\left[u\,(S_1^{3/2}-S^{3/2})+u_1\,(H_1-\frac{nV^2}{2g})\,(\frac{S_2^{3/2}-S_1^{3/2}}{S_2-S_1})\right]$$

$$=2/3\times151\times8.02\left[.635\,(6.31^{3/2}-2.27^{3/2})+.556\,(12.3-\frac{.67\times9^2}{64.5})\,(\frac{8.58^{3/2}-6.31^{3/2}}{8{,}58-6.31})\right]$$

$=27{,}300$ cubic feet per second.

In the above solution we have assumed all the weir crest at the same elevation, and neglect the fact that 16 lineal feet is 3.65 feet higher, as is shown in sketch of Sunol Dam on plate B 11. We must, therefore, reduce the above computed discharge by the amount that would flow through this area. This will be readily accomplished by deducting 16/151 of the difference between the above computed discharge and a discharge from the surface down to the elevation of the crest of the 16-foot section, or when

$H_1=12.3-3.6=8.7$

then we have

$S=2.27;\ S_1=6.31;\ u=0.635,\ a_1=.556;$

$$S_2=S_1+\frac{2v^2\,BK\cos^2\frac{\psi}{2}}{bg\,(H_1-\frac{nV^2}{2g})}=6.31+\frac{2\times(12)^2\times3+\cos^2\frac{20^0}{2}}{32.2\,(8.7-\frac{0.67\,(9)^2}{64.5})}=9.62;$$

$$Q_1=2/3b\sqrt{2g}\left[u\,(S_1^{3/2}-S^{3/2})+u_1\,(H_1-\frac{nV^2}{2g})\,(\frac{S_2^{3/2}-S_1^{3/2}}{S_2-S_1})\right]$$

$$=807.35\left[0.635\,(6.31^{3/2}-2.27^{3/2})+0.556\,(8.7-\frac{.67\,(9)^2}{64.5})\,(\frac{9.62^{3/2}-6.31^{3/2}}{9.62-6.31})\right]=21{,}300 \text{ cu. ft. per sec.}$$

$\frac{16}{151}$ of $(27{,}300-21{,}300)=600$ cu. ft. per sec.

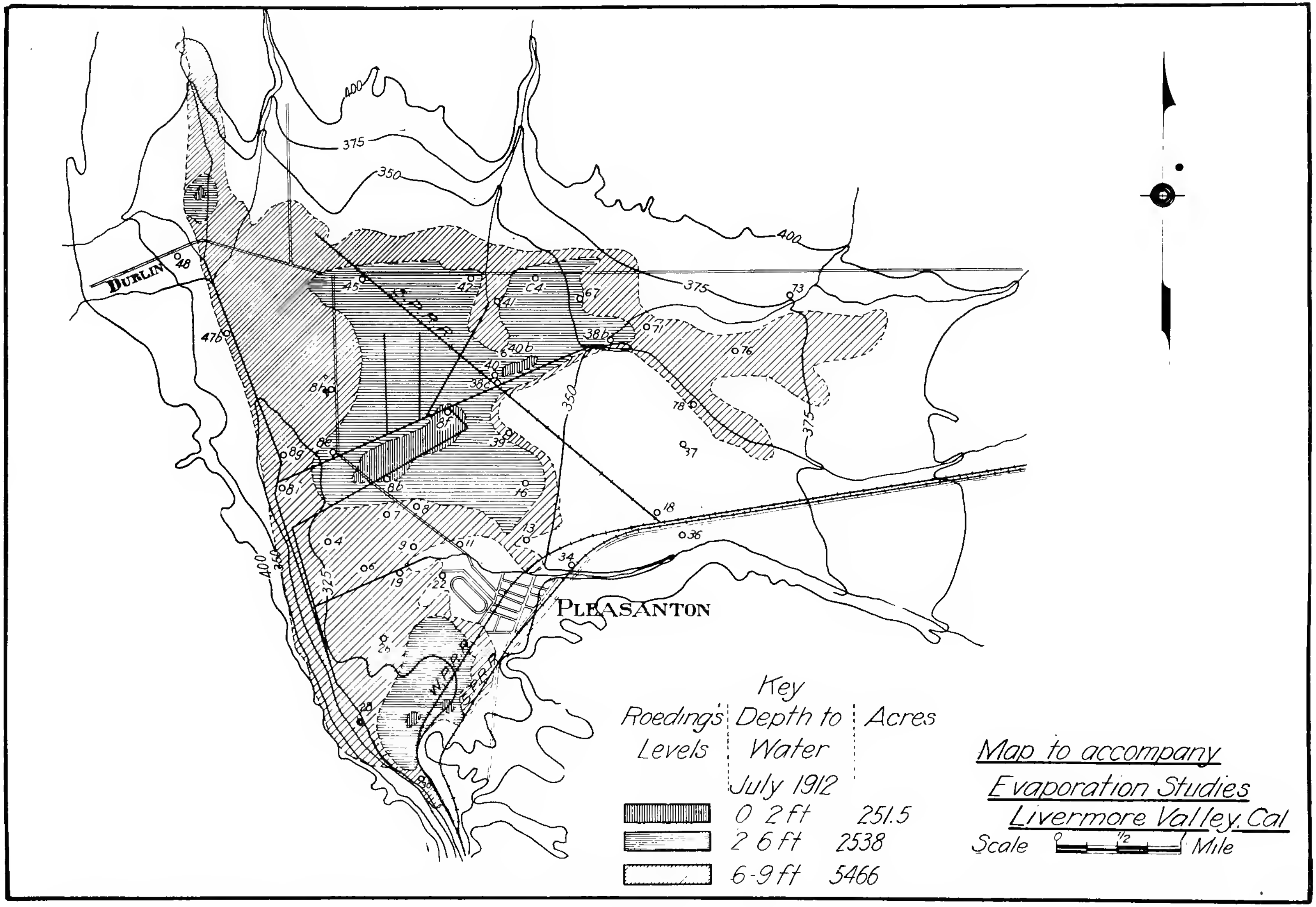
The discharge over the Sunol Dam under the condition of March, 1911, with a 14.1 gage, as computed by Molitor formula, was 27,300—600=26,700 in feet per second.

To summarize, we have:

30,900	Kutter
31,000	Bligh
26,700	Molitor

Mr. Le Conte's discharge curve gives a discharge of 28,800 cu. ft. per second for the same gage height of 14.6 feet.

Note that the lip on the crest of Sunol Dam was worn away about six inches in March, 1911, which was not taken into account in recording the gage heights for high waters, consequently in comparing with Le Conte's discharge curve we have taken a gage height of 14.6 instead of 14.1.



GREAT QUANTITIES OF WATER ARE LOST IN THE WESTERLY PORTION OF LIVERMORE VALLEY BY EVAPORATION FROM SATURATED SOILS.

Appendix D.

EVAPORATION

BY

T. W. Espy,

Assistant Engineer, Spring Valley Water Company.

(Mr. Espy is a Civil and Mining Engineer with many years' experience in hydraulic mining. He was for several years in charge of the hydrographic work and reconstruction of the Imperial Valley Irrigation project, embracing 300,000 acres of land and 1000 miles of canal.—F. C. Herrmann.)

For the purpose of this report consideration must be given to evaporation from large water surfaces and to that from surfaces of soils with varying degrees of saturation. Evaporation from water surface must be applied to the various surface storage reservoirs as it is a loss that is operating constantly, and as this loss is not preventable nor recoverable it affects the possible safe draft to a considerable extent.

It is necessary to consider evaporation from saturated soil surfaces because of the condition that exists in the westerly or lower end of Livermore Valley.

EVAPORATION FROM WATER SURFACE.

The amount of evaporation from a free water surface depends upon the temperature of the water surface and upon the dryness of the air, and is caused by the difference in the vapor pressure at the water surface temperature and the vapor pressure in the air. Several factors affect these causes; those that are most easily measured are the temperature, relative humidity, and wind velocity. The temperature has by far the greatest affect as it acts upon the dew point inversely to the vapor pressure. The air movement affects evaporation rate principally by its secondary effect upon humidity, as without air movement the air in contact with the evaporating surfaces soon approaches saturation and evaporation becomes a minimum.

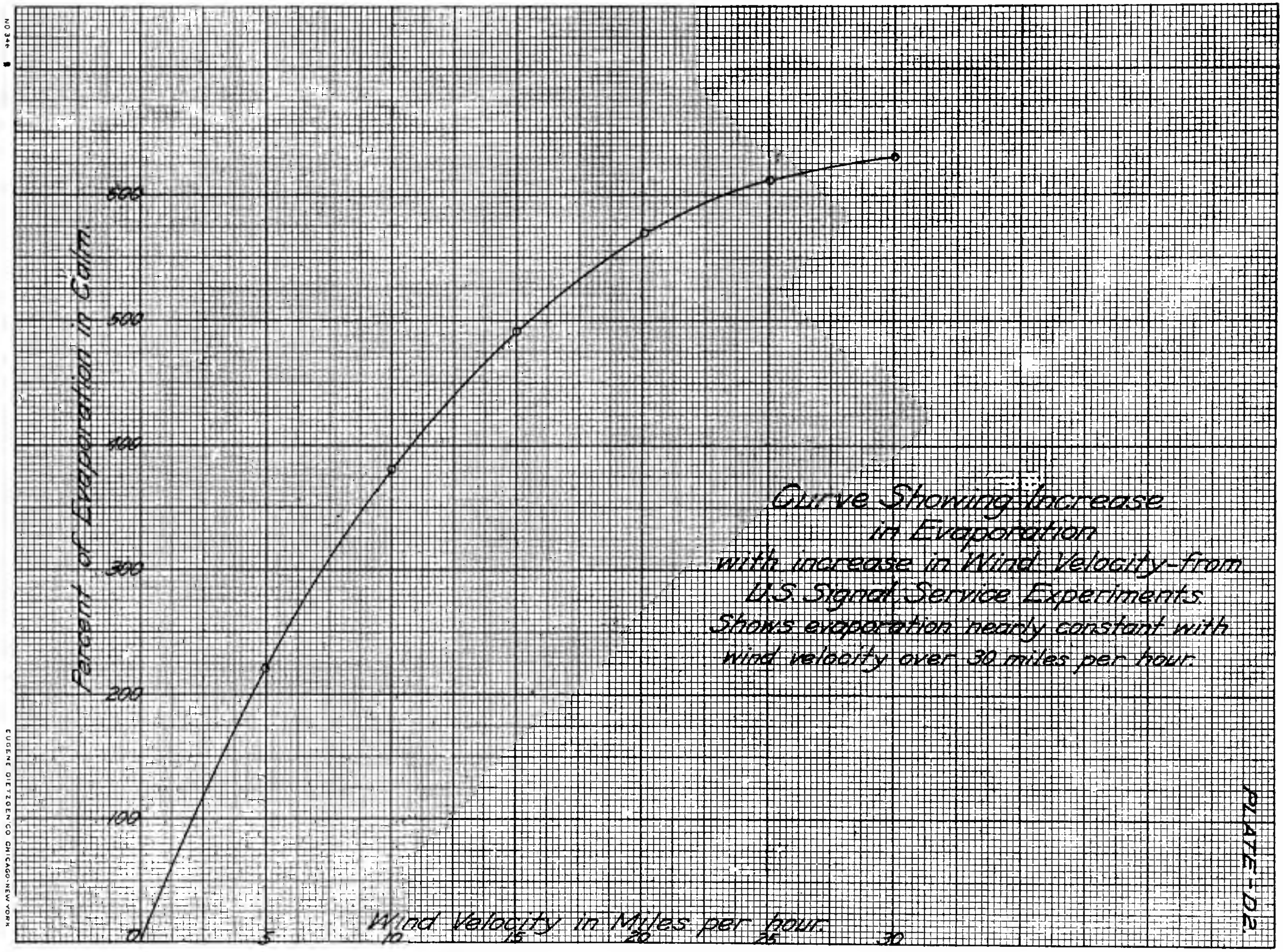
Wind Velocity.

That wind velocity has a great effect upon the rapidity of evaporation is recognized by the most unscientific persons. Perhaps the simplest demonstration of this fact is found in the drying of wet garments. All housewives know that the drying of the weekly wash is much facilitated by placing it in a current of air and they invariably take advantage of this fact. If the garments are dried within doors, all windows are thrown open to give freedom to air movement, and when outside, they are placed on the roof or away from a sheltered place.

The effect of wind velocity upon evaporation is well shown by experiments made by the U. S. Signal Service on evaporation and wind velocity. These experiments were made with the air at a temperature of 84° and a relative humidity of 50%, by whirling Piche's Hygrometers at varying velocities on an arm 28 feet in length. The evaporation was found to be 2.2 times as great with a velocity of 5 miles as in a calm, 3.8 times at 10 miles, 4.9 times at 15 miles, 5.7 times at 20 miles, 6.1 times at 25 miles and 6.3 times at 30 miles an hour. These results, plotted on Plate D2, show that the evaporation due to the increase of wind velocity is very rapid at first but gradually decreases until at after 30 or 35 miles an hour the evaporation is but little affected by increased wind velocity.

Of experiments made at the Colorado State Agricultural College, on evaporation, the Agricultural Experiment Station's Bulletin No. 45 says (page 18):

> "The effect of the wind is to increase the amount of evaporation by bringing unsaturated air in contact with the water, and to give opportunity for the diffusion of the



THIS CURVE SHOWS HOW THE WIND INCREASES THE EVAPORATION.

water vapor. From the working formula derived from the observations in 1889, each mile of wind increased the evaporation by about 2 per cent. Mr. Fitzgerald's experiments at Boston indicate an increase of 2 per cent for each mile of wind."

Evaporation is further shown to be closely governed by wind velocity by Plate D3, taken from U. S. Department of Agriculture's Bulletin No. 248.

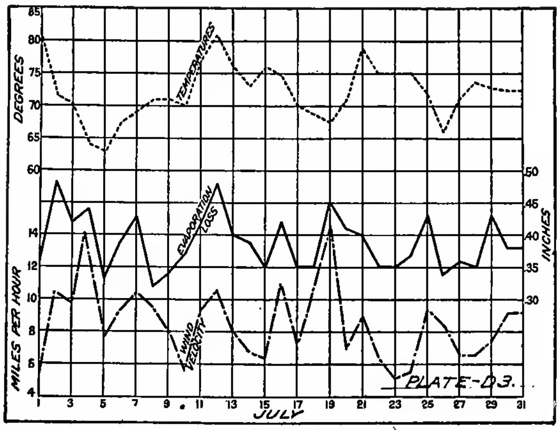


Fig. 23.—Mean temperatures, average wind velocities, and evaporation losses from a free-water surface at Davis, Cal., July 1909.

Water Temperature.

As a rise in the water temperature increases the vapor pressure and causes a larger evaporation, other conditions being the same, a record of the water temperature would be a gage upon the amount of evaporation. This was well demonstrated by experiments carried on in several widely distributed stations in California during 1904-05 by the U. S. Department of Agriculture and shown in table below (Bulletin 248, page 69).

AVERAGE TEMPERATURE AND EVAPORATION THEREFROM.

Average Temperature of Water Surface °F.	Daily Evaporation Inches.
53.4	0.09
61.3	0.19
73.5	0.36
80.4	0.48
88.7	0.60

These records show a direct relation between water surface evaporation and temperature as is easily seen by referring to Plate D4.

In general, water temperature is not obtainable and some other method must be employed in estimating evaporation for a given locality. Air movement, humidity and water temperature are all governed to a large extent by air temperature, therefore the latter has been adopted by many who have had occasion to study evaporation loss as a gage of water surface evaporation.

In commenting on the results shown in the above table the Bulletin says (page 69):

> "As the temperature of the water depends directly upon and follows closely the atmospheric temperature, the latter must be recognized as one of the controling factors in evaporation loss."

Mr. C. E. Grunsky in his article on "Evaporation from the Salton Sea" states (page 163, Eng. News, Aug. 13, 1908):

> "It may be allowable to compare the rate of evaporation during a moderately long time unit, as for a month, directly with the mean temperature of the air for the same time, and to apply the relation so established between temperature and evaporation to regions that are known to have climates similar to those at which evaporation measurements have been made."

The direct relation between evaporation and air temperature is well shown in Plate D-5, 6, and 7, taken from U. S. Department of Agriculture's Bulletin No. 177, pages 36 and 37.

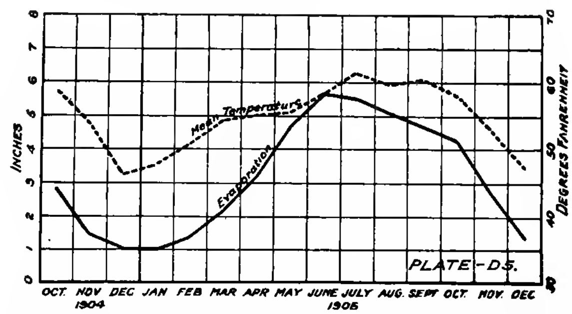


Fig. 10.—Diagram showing relation between temperature and evaporation at Berkeley, Cal

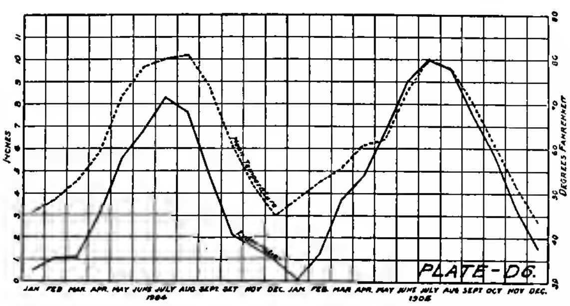
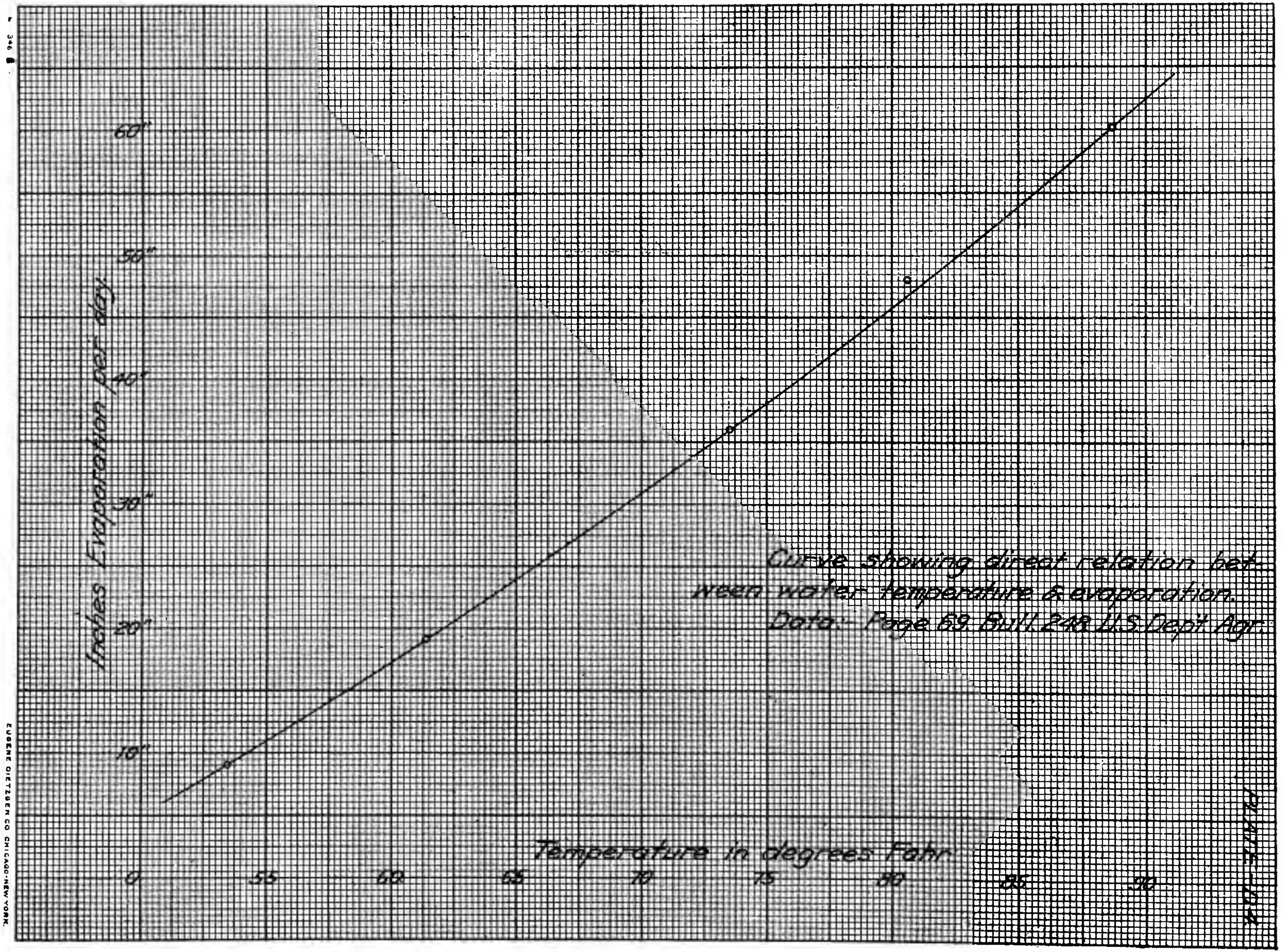


Fig. 12.—Diagram showing relation between temperature and evaporation at Chico, Cal.



THE LOSS FROM EVAPORATION DEPENDS ON THE TEMPERATURE OF THE WATER.

Evaporation Records.

Considerable data has been obtained of the water surface evaporation in various places, but just how close these records apply to the evaporation that would take place from large water surfaces is in all cases questionable.

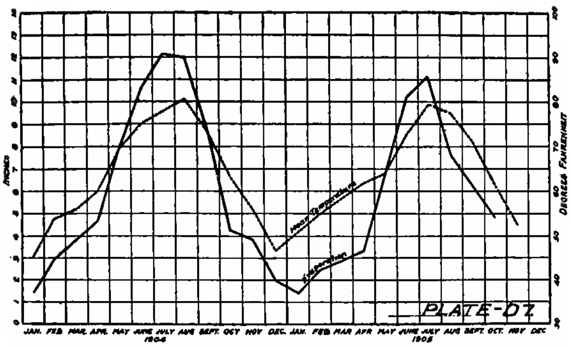


FIG. 13.—Diagram showing relation between temperature and evaporation at Tulare, Cal.

Two methods ordinarily used are either to record the evaporation from tanks floated by means of a raft in a large body of water—as a canal, reservoir or lake,—or to measure the evaporation from a tank sunk into the ground until its top is level with the ground surface.

It has been considered by many that the latter method gives results much higher than should be applied to a large water surface.

Mr. Edwin Duryea, Jr., consulting engineer, made exhaustive observations during the years 1904 and 1905 (results published in Engineering News of Feb. 29, 1912, page 380), in the Santa Clara Valley, near San Jose, California, with eight land plans and three floating pans. While his results as given on table D-8 show the floating pan to evaporate 73.3% the first year and 70% the second year of the land pan, he adopts 80% as his safe reservoir evaporation for Laguna Seca and Upper Gorge reservoir.

This excess of land pan evaporation over water or floating pan evaporation was also found in observations at Kingsburgh, of which Mr. C. E. Grunsky writes (page 164, Eng. News, Aug. 13, 1908):

> "The purpose of the Kingsburgh observations was not to establish any law of evaporation but to ascertain the probable annual total from a water surface. The four-year record at that point showed 3.85 feet as the depth of water evaporating annually from the pan floated in the river, and 4.96 feet as the depth of water evaporating from the pan on the ground."

This water pan evaporation of 78% of the land pan evaporation is believed by Mr. Grunsky to be lower than the actual evaporation from a large water surface, and he continues:

> "It is believed that the evaporation measured from the pan floating in the river at Kingsburgh was somewhat less than would have occurred from a large body of open water, mainly for the reason that some protection was afforded to the pan by high river banks, a fringe of low trees and a near-by bridge, and for the further reason that the river temperature was probably a little below what would have been the temperature of an open body of water. But the pan on the ground probably showed evaporation in excess of what would have taken place from a large water surface, particularly for the reason that the water in this pan was warmer than the water surface of any large water body would have been."

Experiments Conducted by U. S. Department of Agriculture.

Experiments carried on by the U. S. Department of Agriculture in Wyoming and published in Bulletin No. 104 shows well the relation between land pan and water pan evaporation (page 208):

> "To find roughly the difference in the rate of evaporation from the surface of water running in a canal and from the water of an evaporation tank, two records were kept during the season of 1900 at Wheatland. An evaporation tank was placed in the ground in the usual manner. Another tank of similar dimensions was placed in canal No. 2. The latter tank was supported on a raft which was anchored to the banks. All precautions were taken in both cases to prevent water being lost through any other source than evaporation and it is believed that the results of the test are quite accurate. The table given below shows the depths lost during each week from June 2 to October 16. The greatest loss occurred during July, the total evaporation during that month being 19.33 inches from the tank on land and 16.72 inches from the tank in the water. The table given below shows the evaporation from each tank and the excess of evaporation from the land tank over the one in the water for each week and for the season.

TABLE D—8.

SYNOPSIS OF OBSERVED YEARLY EVAPORATIONS, SANTA CLARA COUNTY, CALIFORNIA, AND FLOATING-PAN EVAPORATION AS A PER CENT OF LAND-PAN EVAPORATION. (TABLE V, ENG. NEWS, FEB, 29, 1912)

GROUP.	Nearby rain-gage, no.	1904 Inches evaporation.	1904 Floating pan as per cent of land pan. Pairs of pans.	1904 Floating pan as per cent of land pan. Means of groups.	1905 Inches evaporation.	1905 Floating pan as per cent of land pan. Pairs of pans.	1905 Floating pan as per cent of land pan. Means of groups.	Means of two years, in. equal %
Coyote Valley Group—								
Pan No. 1, Weber, land	34	49.8	....	49.8 in.	46.7	....	46.2 in.	48.0
Pan No. 2, Lower gorge, land	29	49.7	....		45.8	....		
Laguna Seca Group—								
Pan No. 3, Bailey avenue, land	33	53.8	....		55.4	....		
Pan No. 4, Laguna Seca north, land	31	62.3	.... =100%	56.6 in.=100%	60.4	.... =100%	56.9 in.=100%	56.7=100%
Pan No. 5, Laguna Seca west, land	32	53.8	=100%		54.8	=100%		
Pan No. 6, Laguna Seca west, floating	31	39.4	= 73.3	41.2 in.= 72.8	43.1	= 78.6	48.3 in.= 85.0	44.8= 79.1
Pan No. 7, Laguna Seca east, floating	31	43.0	.... = 69.0		53.5	.... = 88.6		
Upper Gorge Group—								
Pan No. 8, San Felipe dam, land	35	41.7	....		52.3	....		
Pan No. 9, San Felipe reservoir, land	7	47.2	....	45.1 in.	45.2	....	51.0 in.	48.1
Pan No. 10, Upper Gorge, land	40	46.5	=100%	.... =100%	55.4	=100%	.... =100%	51.0=100%
Pan No. 11, Upper Gorge, floating	40	34.3	73.8	.... 73.8=	30.4	= 54.9	.... = 54.9	32.3= 63.4
Mean of Group Means—								
Land-pan evaporation				100%			100%	100%
Floating-pan evaporation				73.3			70%	71.3

ADOPTED SAFE RESERVOIR EVAPORATIONS, INCHES PER YEAR. (TABLE VI, ENG. NEWS, FEB. 29, 1912)

Coyote Valley land pans .... =say 54 inches per year.
Coyote Valley reservoir evaporations .... =say 80% of land pans=say 44 inches per year.
Laguna Seca land pans .... =say 64 inches per year.
Laguna Seca reservoir evaporations .... =say 80% of land pans=say 52 inches per year.
Upper Gorge land pans .... =say 56 inches per year.
Upper Gorge reservoir evaporations .... =say 80% of land pans=say 45 inches per year.

The adopted reservoir evaporations were fixed on only after a careful individual comparison with all the Pan-Records and Group Records above. One %-relation of Table V (88.6%) is apparently somewhat disregarded, but it is believed that the adopted values are amply safe, especially that for the Upper Gorge Reservoir. It is believed that the adopted Upper Gorge evaporation, 45 inches per year, will be amply safe for all the streams of the Bay Cities Water Company except Laguna Seca.

EVAPORATION AT WHEATLAND, WYO., 1900.

Date.	Evaporation from tank on land	Evaporation from tank in water	Excess from tank on land	
			Depth	Percentage
Week ended—	Inches	Inches	Inches	
June 9	3.50	3.00	0.50	17
June 16	3.95	3.35	0.60	18
June 23	4.00	3.60	0.40	11
June 30	4.28	3.78	0.50	13
July 7	4.75	4.25	0.50	12
July 14	4.18	3.98	0.20	5
July 21	5.59	4.39	1.20	27
July 28	3.98	3.58	0.40	11
August 4	3.50	2.60	0.90	35
August 11	3.63	2.63	1.00	38
August 18	3.40	2.60	0.80	31
August 25	3.40	2.40	1.00	42
September 1 ..	3.40	3.00	0.40	13
September 8 ..	3.40	2.20	1.20	55
September 15 ..	2.94	2.44	0.50	20
September 22 ..	2.25	1.75	0.50	29
September 29 ..	1.98	1.48	0.50	34
October 6	2.02	1.67	0.35	21
October 13	2.25	1.75	0.50	29
Total	66.40	54.45	11.95	22

It is interesting to note that there is always an excess of evaporation from the land tank and that it never exceeded 1.2 inches for any week. Why the difference in the loss between the two tanks should vary as much as it does can not be explained. It is probably in a large measure due to the fact that the earth heats more quickly than the water. The evaporation from the tank on land would, under this assumption, be more quickly affected by every change in the temperature than from the tank in the water. It will be noticed that during the time the record was kept 66.4 inches, or 5 feet 6.4 inches of water in depth, was lost from the tank in the ground, and 54.45 inches, or 4 feet 6.45 inches, was lost from the tank in the water. The difference between the losses in depth from the two tanks is therefore about one foot.

When it is considered that the water in the canal is constantly moving and is subject to more or less disturbance the loss from its surface will probably more nearly approximate the results from the land-tank measurements. The results obtained from the tank in the water will probably more nearly apply to the loss of water from the reservoir surface. However, it will likely be excessive for anything except quite shallow basins."

It must be noted that the above water pan was placed in a flowing canal and that on account of the water movement in the canal the evaporation from the canal water was obviously greater than from the still water of the pan. Also that on account of the greater evaporation from the canal water it must have been constantly drawing upon the pan for heat, thus reducing the amount of evaporation that should have taken place in the pan, had the water in the canal not been in motion.

This ability of flowing water to reduce the water pan evaporation is shown by experiments made at the Agricultural Experiment Station at Fort Collins, Colorado, and published in Bulletin No. 45 of the State Agricultural College. In these experiments observations of water pan evaporation were made upon a pan placed in a ditch passing through the State College grounds and upon several small lakes or reservoirs in the immediate neighborhood.

The Bulletin says (page 23):

"A similar tank was placed in the Arthur ditch where it passes through the College grounds. Observations were taken daily. While not the same as reservoir conditions it gives data for comparison:

	Inches.—	
June, 1889...	2.89...	Record based on 16 days
July, 1889...	4.13...	" " 31 "
Aug., 1889...	3.94...	" " 21 "

From the above data we obtain the basis for estimating the evaporation at the same rate for the calendar months:

TABLE XIII.

Lee Lake, 1896.			Lee Lake, 1897.		
Month	Evaporation inches	No. days Record	Month	Evaporation inches	No. days Record
			May ...	4.31	24
June...	6.36	15	June...	9.55	21
July ...	9.11	32	July ...	8.53	21
Aug....	7.25	31	Aug....	8.61	32
Sept...	5.20	32	Sept...	8.40	31
Oct....	4.17	28	Oct....	4.60	32
Loomis Lake, 1897.			**Claymore Lake, 1897.**		
May ...	7.89	20	May ...	5.22	14
June...	7.91	26	June...	....	..
July ...	11.87	20	July ...	....	..
Aug....	9.02	32	Aug....	8.93	10
Sept...	....	..	Sept...	4.81	21
Oct....	4.89	32	Oct....	1.62	23
Warren's Lake, 1889.			**Warren's Lake, 1890.**		
May ...	....	..	May ...	7.71	13
June...	....	..	June...	8.40	7
July ...	7.37	37	July ...	5.41	29
Aug....	....	..	Aug....	8.06	38
Sept...	7.25	30	Sept...	....	..
Oct....	5.61	21	Oct....	....	..

It will be noticed that the evaporation from the tanks as given is much greater than the corresponding tank on the grounds of the Agricultural College. This difference is partially but not entirely due to temperature. The tanks in the lakes are more freely

exposed to the wind than the standard tank, and this would therefore make a great difference. The tanks are more or less agitated by waves, and in consequence the water surface exposed to the air is larger than the cross section of the tank. A film of water is also left on the metal sides of the tank with every movement, and this is apt to be of higher temperature than the water in the lake or in the tank, and evaporates more rapidly. The influence has been noticed by Mr. Trimble, who made the observations in 1896 and some of those in 1897, and suggested as a cause of some of the excess of evaporation observed from the lakes. The effect may be considerable, but how much is uncertain. The wave action differs in the different lakes. In Lee Lake the weeds extend so near the surface that there is little opportunity for wave formation. In the other two lakes the effect is greater. As the waves also increase the area of the surface of the lakes which is exposed to the air likewise, the results are possibly closer to the loss from a lake exposed to the wind than if the tank had been stationary.

The effect of such increase of surface may be considerable. We have made no experiments to determine the possible effect. The only ones reported are some by Maurice Aymard, a French engineer stationed in Algeria, whose report on Irrigation in Spain as preliminary to the construction of a reservoir which has but recently been built, in classic in irrigation literature. The observations were carried on for less than four days in 1849. Tanks 20 inches (50cm) in diameter and 2 feet high were made. In one the water was still; in the other an iron disk nearly of the same diameter as the tank, with holes through it, was slowly raised and lowered in the tank. The water passing through the numerous small holes kept the surface in agitation, something like the surface in small ditches with rapid fall. The loss under these conditions was more than a third more from agitated than from quiet water, or a loss of 1.66 inches from the quiet water, and 2.32 from the rough water."

The conclusions to be arrived at from the foregoing study is that evaporation from a large water surface is much less than is obtained by the usual land pan method, and that perhaps 80% is a safe factor to apply to land pan observations.

A wide range in the total annual evaporation under different climatic conditions is shown by the following table taken from Prof. Hilgard's work on Soils:

TABLE SHOWING EVAPORATION FROM WATER SURFACE EXPOSED IN SHALLOW TANKS NEAR WATER OR GROUND SURFACE.

		Years.	Inches.
Rothamsted	England	9	17.80
London	"	14	20.66
Oxford	"	5	31.04
Munich	Germany	?	24.00
Endrup	Denmark	10	27.09
Cambridge	Massachusetts	1	56.00
Syracuse	New York	1	50.20
Logan	Utah	1	52.39
Tucson	Arizona	1	75.80
Fort Collins	Colorado	11	41.00
Fort Bliss	Texas	1	82.70
San Francisco	California	..	45 to 50
Sweet Water Res. San Diego	"	1	57.60
Peking	China	?	38.80
Demerara	South America	3	35.12
Bombay	East India	5	82.28
Petro-Alexandrowsk	West Turkestan	?	96.40
Kimberley	South Africa	?	98.80
Alice Springs	South Australia		103.50
Pomona	California	1904	66.92
Tulare	"	1904	74.68
Calexico	"	1904	108.23

Considerable evaporation data has been collected through California which shows a wide range in evaporation. Some of these evaporation records are tabulated in Table D-9.

In estimating the water surface evaporation applicable to our proposed Alameda System Reservoirs we have accepted results obtained by Edwin Duryea, Jr., in the Santa Clara Valley, California, and results obtained by Mr. C. E. Grunsky at Kingsburgh, California, as being on account of the close proximity and similarity of climatic conditions, most applicable. These we have plotted on Plate D-10 as a function of mean monthy temperature along with results obtained in the Owens Valley and Berkeley, and from them constructed a curve applicable to Livermore Valley. From this curve we obtain a mean annual evaporation of 48.18 inches, shown in Table D-11.

TABLE D 9

AVERAGE MONTHLY AND ANNUAL EVAPORATION—CALIFORNIA STATIONS.

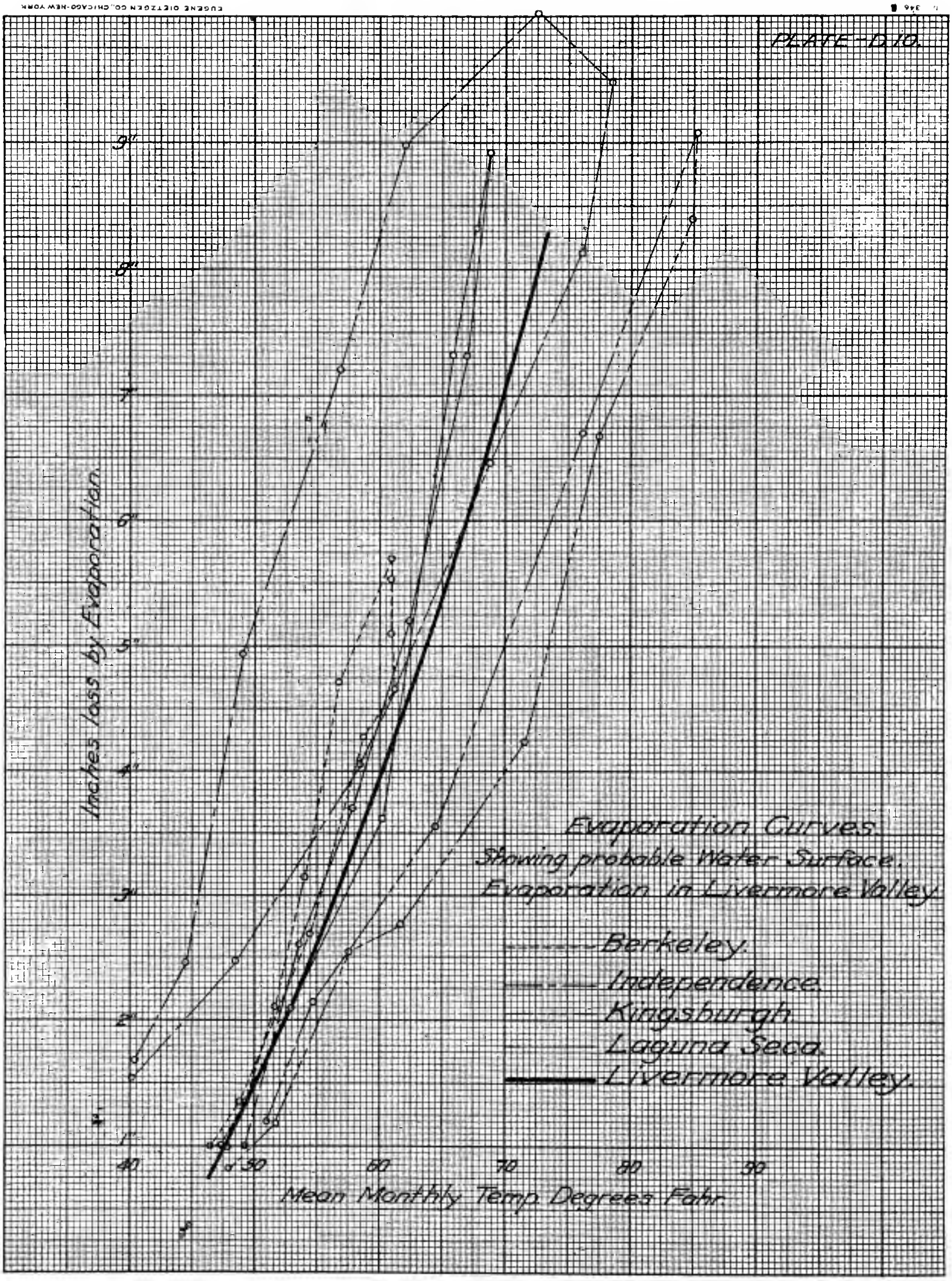
Month.	Chico 1904-05	Berkeley 1905	Tulare 1904-05	Pomona 1904-05	Salton Sea 1907-08	Calexico 1904-5	Laguna Seca (Adopted)	Upper Gorge (Adopted)	Lake Tahoe 1902-04	Kings-burgh 1881-85	Independ-ence	Bishop 1904	Sweet-water Res. 1889-97	Arrow-head Res. 1895-97
January	.30	1.00	1.46	2.35	2.16	3.56	1.00	.90	.97	.81	1.68	4.35	2.37	.33
February	1.14	1.36	2.74	2.11	2.64	4.03	1.00	.90	.73	1.18	2.45	2.21	1.99	.53
March	2.44	2.11	3.35	3.71	3.00	6.65	2.60	2.30	1.23	2.54	4.92	4.48	3.15	1.03
April	3.88	3.14	3.97	4.54	5.16	7.14	3.70	3.10	1.99	2.76	7.18	6.41	4.92	4.12
May	6.21	4.70	7.38	6.24	8.52	9.65	5.20	4.50	2.49	4.22	8.94	11.02	5.58	4.30
June	7.92	5.68	10.50	7.97	8.88	13.37	7.30	6.30	3.38	6.66	10.00	7.88	6.90	6.42
July	9.17	5.52	11.63	9.14	8.28	11.45	8.90	7.70	4.48	8.37	9.45	6.95	7.43	6.32
August	8.61	5.09	9.80	9.19	6.36	9.75	8.30	7.20	4.28	9.05	8.10	5.24	7.66	5.62
September	6.16	4.65	7.46	7.34	11.16	8.22	7.30	6.30	3.65	6.69	6.45	3.83	6.45	4.69
October	3.95	2.27	4.53	5.32	6.84	7.77	3.60	3.10	3.09	3.56	4.05	2.82	5.72	3.62
November	2.46	2.68	3.88	4.05	6.48	4.32	2.10	1.80	2.48	2.13	2.48	1.73	4.52	1.24
December	1.23	1.35	2.00	2.94	4.20	3.45	1.00	.90	1.29	1.18	1.54	3.21	2.38	.93
Annual	53.47	41.55	68.70	64.90	73.68	89.36	52.00	45.00	30.06	49.15	67.24	60.13	59.07	39.15

TABLE D 11

RATES OF EVAPORATION FROM WATER SURFACE.

	INDEPENDENCE			KINGSBURGH			LAGUNA SECA			BERKELEY			LIVERMORE		
	Mean monthly tempera-ture	Evapora-tion in inches	% of an-nual evapora-tion	Mean monthly tempera-ture	Evapora-tion in inches	% of an-nual evap-oration	Mean monthly tempera-ture	Evapora-tion in inches	% of annual evapo-ration	Mean monthly tempera-ture	Evapora-tion in inches	% of annual evapora-tion	Mean monthly tempera-ture	Evapora-tion in inches	% of annual evapo-ration
January	40.4	1.68	2	47.98	0.81	2	46.5	1.0	2	47.6	1.00	2.4	49.3	1.32	2.7
February	44.6	2.45	4	51.74	1.18	2	49.3	1.0	2	49.7	1.36	3.3	51.6	1.80	3.7
March	49.4	4.92	7	57.68	2.54	5	53.7	2.6	5	51.7	2.11	5.1	53.8	2.32	4.8
April	56.8	7.18	11	61.80	2.76	6	57.8	3.7	7	54.0	3.14	7.6	56.9	3.10	6.4
May	62.8	8.94	13	71.68	4.22	9	62.5	5.2	10	57.3	4.70	11.3	61.4	4.30	8.9
June	72.6	10.00	15	77.72	6.66	14	67.0	7.3	14	60.9	5.68	13.7	67.6	6.20	12.9
July	78.6	9.45	14	84.90	8.37	17	68.8	8.9	17	61.0	5.52	13.3	70.1	7.01	14.6
August	76.2	8.10	12	85.02	9.05	18	67.9	8.3	16	60.9	5.09	12.2	69.6	6.84	14.2
September	68.9	6.45	10	76.42	6.69	14	66.0	7.3	14	61.3	4.65	11.2	68.2	6.37	13.2
October	58.7	4.05	6	64.62	3.56	7	60.3	3.6	7	58.9	4.27	10.3	62.8	4.75	9.9
November	48.6	2.48	4	54.90	2.13	4	52.8	2.1	4	54.6	2.68	6.4	54.9	2.60	5.4
December	40.2	1.54	2	51.1	1.18	2	48.0	1.0	2	48.9	1.35	3.2	50.5	1.57	3.3
Annual	58.15	67.24	100	65.46	49.15	100	58.4	52.0	100	55.6	41.55	100.0	59.7	48.18	100.0

NOTE: Livermore evaporation taken from curve, Plate D 10. For Kingsburgh, temperature of Fresno adopted. For Laguna Seca, temperature of Gilroy adopted.



THE EVAPORATION OF THE LIVERMORE VALLEY WAS DETERMINED FROM MANY OBSERVATIONS.

EVAPORATION FROM SOILS.

In addition to temperature, humidity, and wind velocity, the rate of evaporation and transpiration from soils and vegetation is affected by varying soil conditions, such as relative moistness of the soil, the mechanical, mineralogical and chemical composition of the soil and the character of the vegetation covering the surface.

The amount of evaporation from soils has been extensively observed in California and the West by the U. S. Department of Agriculture and results are published in Bulletins Nos. 177 and 248. These observations were made for the primary purpose of determining the amount of evaporation from soils containing varying percentages of water and methods of preventing this loss. Their results are more interesting to us as showing the relation between water surface evaporation and soil evaporation with water table at different depths.

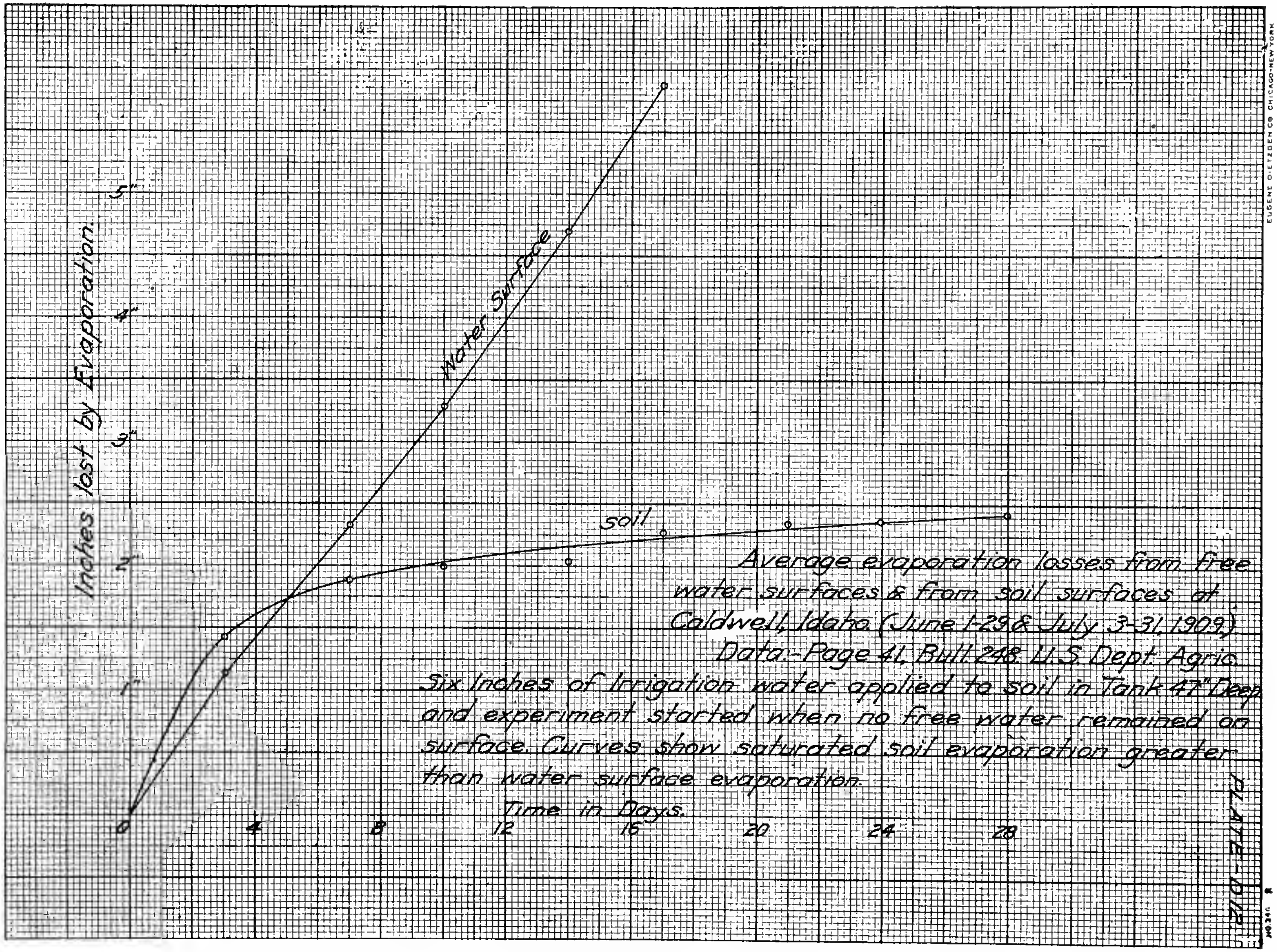
The equipment used were water jacketed galvanized iron tanks about 24 inches in diameter and 27 inches deep. These were filled with soil and sunk into the ground until the tops were even with the surface. A six-inch-irrigation was applied to the surface of the soil, and when it had percolated until no free water remained upon the surface, the tanks and contents were weighed. The tank was again weighed at various intervals, the loss in weight representing the evaporation loss. These experiments show that the evaporation of the soil when saturated was greater than water surface evaporation. Some of the results are tabulated and are shown with diagrams on Plates D 12, 13, 14 and 15.

AVERAGE EVAPORATION LOSSES FROM FREE-WATER SURFACE AND FROM CULTIVATED AND UNCULTIVATED SURFACES AT CALDWELL, IDAHO (JUNE 1-29 AND JULY 3-31, 1909).

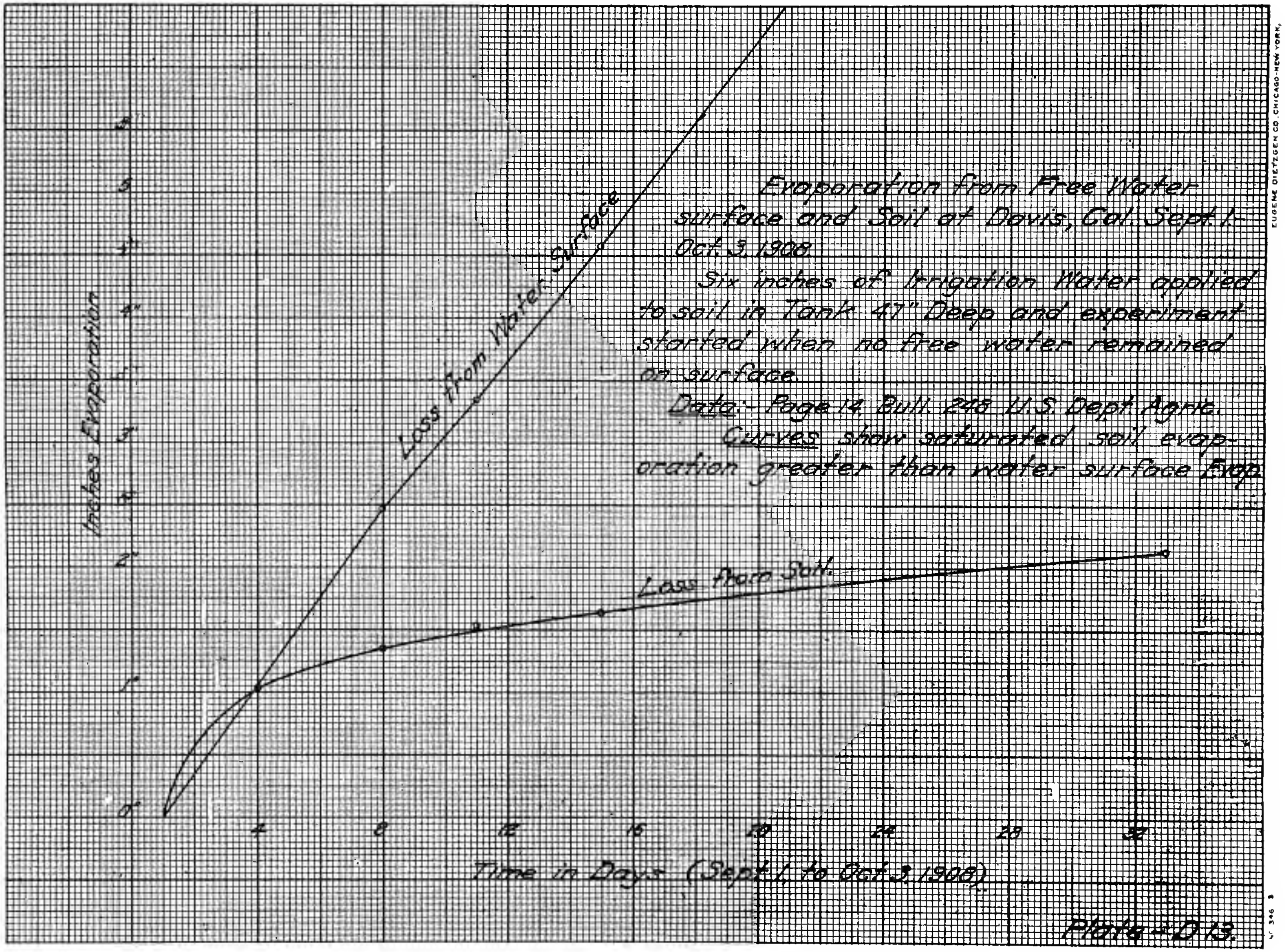
Period	Days	Loss from water surface	Cultivated				Uncultivated			
			Tanks 1 and 2		Tanks 3 and 4		Tanks 5 and 6		Tanks 7 and 8	
Average weight of tanks at beginning of experiment, pounds....	..	.....	1,172.2		1,185		1,172		1,169	
Average loss:		Inches	Pounds	Percent	Pounds	Percent	Pounds	Percent	Pounds	Percent
First	3	1.15	20.40	21.7	20.25	21.6	22.00	23.4	22.50	23.9
Second	4	1.19	3.35	3.6	2.90	3.1	7.10	7.6	7.10	7.6
Third	3	.95	.65	.7	1.00	1.1	1.25	1.3	1.75	1.9
Fourth	4	1.42	.50	.5	.00	.0	1.00	1.1	.75	.8
Fifth	3	1.17	3.00	3.2	2.75	2.9	3.40	3.6	3.40	3.6
Sixth	4	1.50	1.75	1.9	1.35	1.4	1.75	1.9	1.35	1.4
Seventh	3	1.08	.25	.3	.25	.3	.25	.3	.25	.3
Eighth	4	1.35	.90	1.0	.90	1.0	1.00	1.1	.75	.8
Total	28	9.1	30.80	32.9	29.40	31.4	37.75	40.3	37.85	40.3
Equivalent loss in inches	..	.....		1.91				2.42		

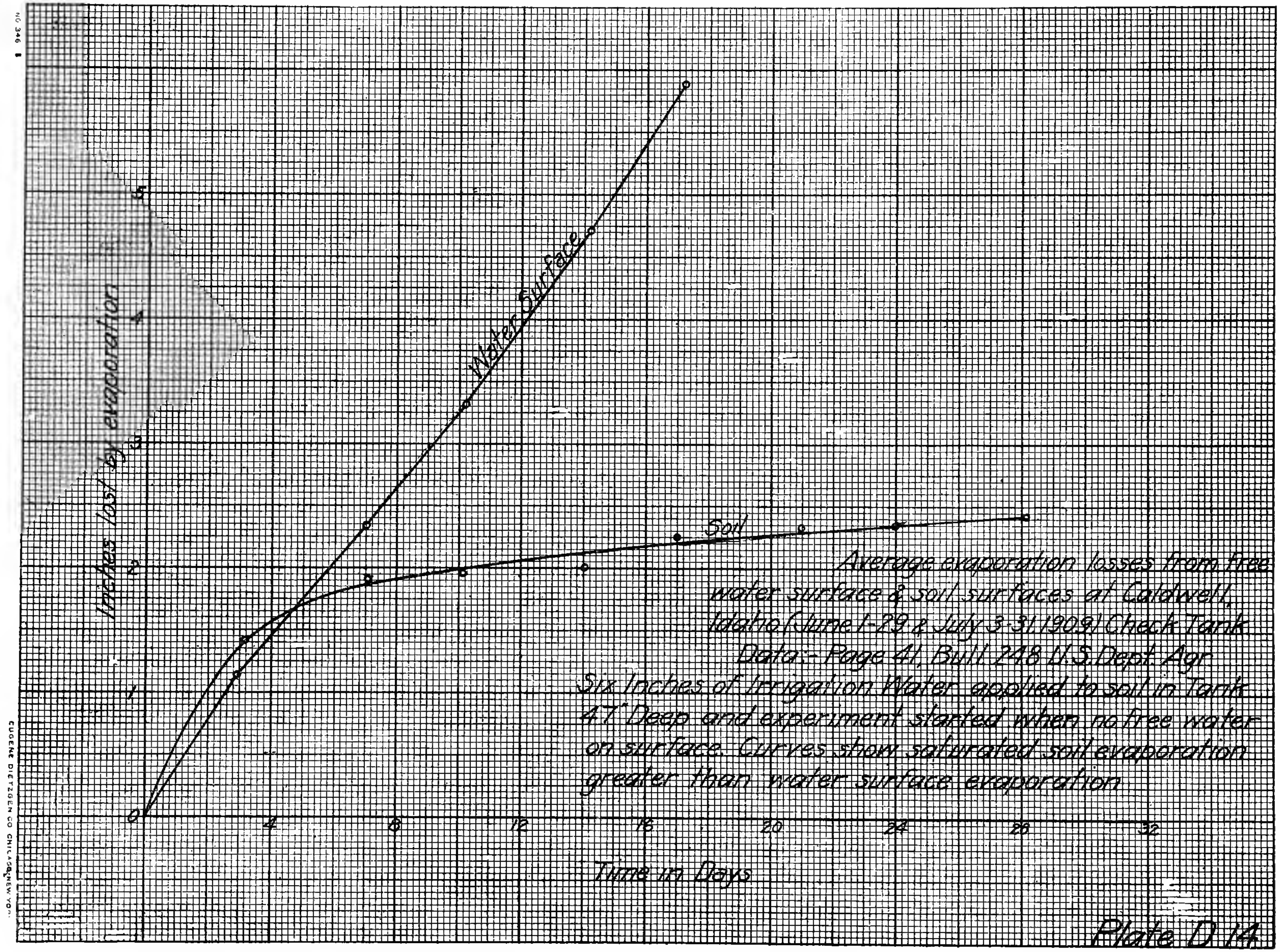
AVERAGE EVAPORATION LOSSES FROM FREE-WATER SURFACES AND FROM CULTIVATED AND UNCULTIVATED SURFACES AT WILLISTON, N. DAK. (AUG. 4 TO 24 AND AUG. 24 TO SEPT. 14, 1909).

Period	Days	Loss from water surface	Cultivated				Uncultivated			
			Tanks 1 and 2		Tanks 3 and 4		Tanks 5 and 6		Tanks 7 and 8	
Average weight of tanks at beginning of experiment, pounds...	..	....	1,042		1,040		1,050		1,010	
Average loss:		Inches	Pounds	Percent	Pounds	Percent	Pounds	Percent	Pounds	Percent
First	3	0.62	11.15	11.9	12.45	13.2	11.55	12.3	9.45	10.0
Second	4	.83	3.85	4.1	2.65	2.8	4.35	4.6	3.75	4.0
Third	3	.56	3.00	3.2	4.10	4.4	4.95	5.3	3.40	3.6
Fourth	4	.74	3.50	3.7	2.25	2.4	4.10	4.4	4.60	4.9
Fifth	3	.57	2.30	2.4	3.80	4.1	6.35	6.8	5.70	6.1
Sixth	4	.89	4.45	4.7	3.70	3.9	2.30	2.4	2.00	2.1
Total	21	4.21	28.25	30.0	28.95	30.8	33.60	35.8	28.90	30.7
Equivalent of average total loss in inches	..	....			1.82				1.99	

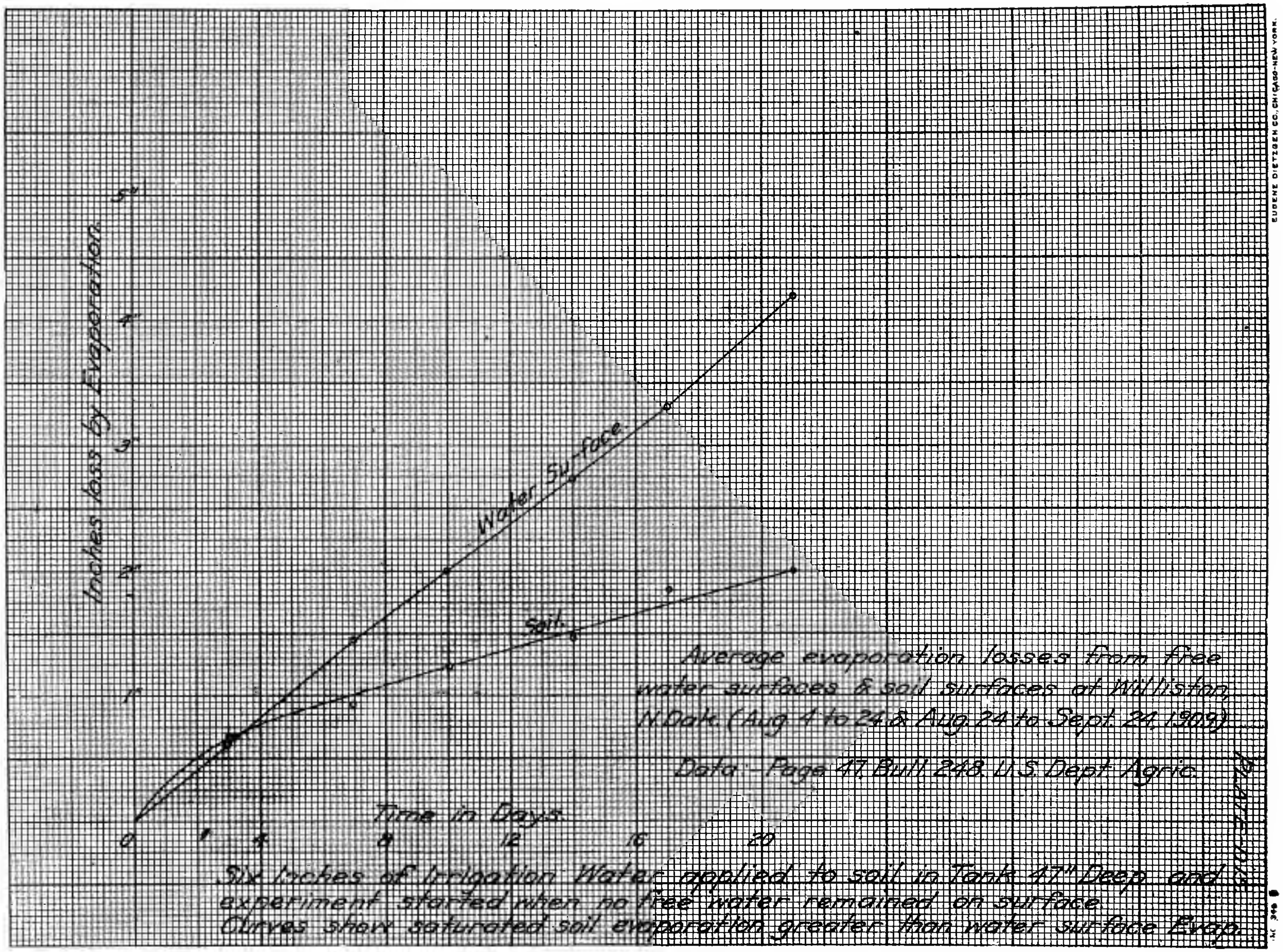


THE U. S. DEPT. OF AGRICULTURE APPRECIATES THE LARGE WATER LOSS FROM SATURATED SOILS.


Evaporation from Free Water surface and Soil at Davis, Cal. Sept. 1-Oct. 3. 1908.
Six inches of Irrigation Water applied to soil in Tank 47" Deep and experiment started when no free water remained on surface.
Data:- Page 14. Bull. 248 U.S. Dept. Agric.
Curves show saturated soil evaporation greater than water surface Evap.
Loss from Water Surface
Loss from Soil.
Inches Evaporation
Time in Days (Sept. 1. to Oct. 3. 1908).
4
8
12
16
20
24
28
32
Plate-D 13.
EUGENE DIETZGEN CO. CHICAGO-NEW YORK.



TRANSPIRATION FROM SOILS IN IDAHO ALSO SHOW LARGER LOSS THAN FROM WATER SURFACE.



EXPERIMENTS ON SOIL TRANSPIRATION CARRIED ON IN ALL PARTS OF THE WEST.

A comparison of evaporation from soil and water surface is given on page 46 of U. S. Dept. of Agriculture's Bulletin No. 177 and is shown in table below. These experiments indicate that the evaporation from a saturated soil may be as much as 2½ times as great as from a free water surface.

Extensive experiments were carried on in Owens River Valley where the artesian conditions are strikingly similar to those of the Livermore Valley, by Mr. Chas. H. Lee under the direction of the Los Angeles Aqueduct Commission and some of his results are published in the Engineering News of Oct. 12, 1911. Mr. Lee in a special report states that two of the conclusions justified by the Owens River Valley experiments are:

1. "There is a definite depth below which evaporation from ground water ceases, and

2. Soil evaporation decreases directly with the depth of the ground water."

This, together with the Department of Agriculture's results of saturated soil evaporation, as shown above, would indicate that even though the water table was considerably below the surface of the ground, the evaporation would be as much or more than from a shallow water surface.

Mr. Lee's conclusions are further borne out by the following tables and Figs. 7 and 9, taken U. S. Department of Agriculture's Bulletin No. 177, pages 32 and 35:

EVAPORATION FROM SOILS AT ARLINGTON HEIGHTS.

Numbers of tanks.	Initial weight of soil and tank, pounds.	Amount of water added, pounds.	Loss by evaportaion in ten days. Pounds.	Inches.	Per cent.
1 and 3 ...	962.4	0	6.3	0.4	....
2 and 4....	940.8	40	15.4	1.0	38.5
5 and 7 ...	941.5	70	19.1	1.2	27.3
6 and 8....	950.0	100	23.9	1.5	28.9

EVAPORATION FROM FREE-WATER SURFACE AND FROM TANKS WITH MULCHES OF DIFFERENT DEPTHS AT DAVIS, CAL., SEPT. 1 TO OCT. 3, 1908 (6 INCHES OF IRRIGATION WATER APPLIED.)

Periods	Loss from water surface	Loss from soil. No mulch tanks 1 and 2		3-inch mulch tanks 3 and 4		6-inch mulch tanks 5 and 6		9-inch mulch tanks 7 and 8	
Average weight of tanks Sept. 1, pounds.......	....	1,104.7		1,090		1,082		1,085.2	
Average loss:	Inches	Pounds	Percent	Pounds	Percent	Pounds	Percent	Pounds	Percent
Sept. 1-4.............	1.07	16.75	17.8	1.75	1.9	0.00	0.0	0.00	0.0
Sept. 4-8.............	1.40	4.50	4.8	.75	.8	.25	.3	[1]—.50	—.5
Sept. 8-11.............	.89	3.00	3.2	2.25	2.4	.75	.8	[1]—.25	—.3
Sept. 11-15............	1.23	1.50	1.6	2.50	2.7	.00	.0	.00	.0
Sept. 15-Oct. 3.........	5.60	8.00	8.5	7.00	7.4	4.75	5.0	2.25	2.4
Total loss, 32 days...	10.19	33.75	35.9	14.25	15.2	5.75	6.1	1.50	1.60
Equivalent loss, in inches	....	2.15		.91		0.39		.10	

[1]—Due to slight inaccuracies in weighing.

EVAPORATION FROM SOIL AND WATER.

Kind of soil and percentage of free water	Mean temperature taken morning, noon and evening in degrees Fahrenheit: Air in shade °F.	Soil in shade °F.	Soil in sun °F.	Moist soil °F.	Surface of water °F,	Weekly evaporation: Soil Inches	Water Inches
Sandy loam—saturated	71	76	95	83	77	4.75	1.88
Sandy loam—17.5	76	78	106	..	80	1.33	1.94
Sandy loam—11.9	76	78	106	..	80	1.13	1.94
Sandy loam—8.9	76	78	108	..	80	.88	1.94
Sandy loam—4.8	76	78	108	..	80	.25	1.94

EVAPORATION FROM TULARE SOILS WHICH RECEIVED DIFFERENT AMOUNTS OF WATER, JUNE 15 TO SEPTEMBER 15, 1904.

Numbers of tanks	Initial Weight of soil Pounds	Amount of water applied Pounds	Inches	Loss by evaporation Pounds	Inches	Per cent
1 and 2..........................	319.5	0.0	0.0	3.8	....	.....
3 and 4..........................	324.0	27.4	3.3	29.1	3.5	106.0
5 and 6..........................	317.8	41.0	4.9	38.5	4.6	94.0
7 and 8..........................	314.0	54.7	6.6	45.7	5.5	83.6
9 and 10.........................	311.5	68.4	8.2	54.7	6.6	80.0
11 and 12........................	316.3	82.1	9.8	65.3	7.9	79.5

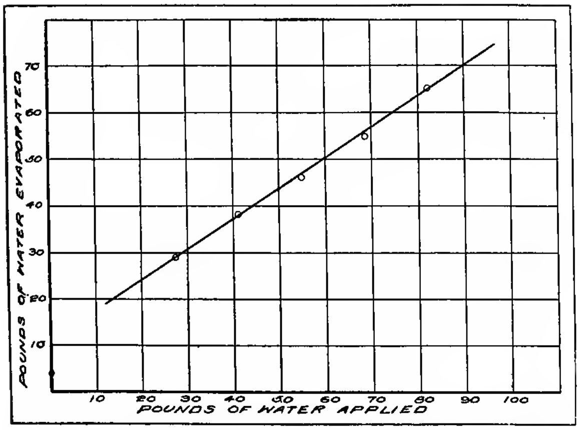


Fig. 7.—Diagram showing relation between amount of water and loss by evaporation as determined by experiments with Tulare soils, June 15 to September 15, 1904.

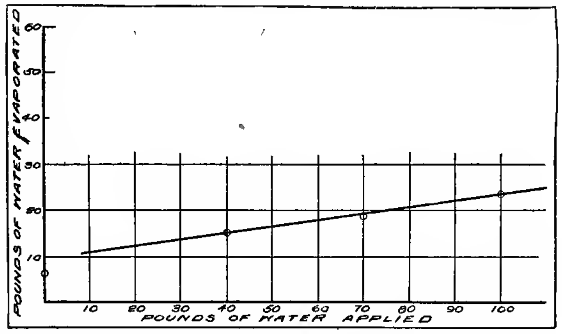


FIG. 9.—Diagram showing relation between amount of water and loss by evaporation as determined by experiments with Riverside soils

Some explanation of the increase of moist soil evaporation over water surface evaporation is obtained from the following diagram, taken from U. S. Department of Agriculture's Bulletin No. 177, page 43, showing the effect of air temperature and sun rays on water temperature, dry soil temperature and moist soil temperature. This diagram shows that soils absorb much more heat than does water in a tank, therefore causing the moisture in the soil to have a much higher vapor pressure than the tank water.

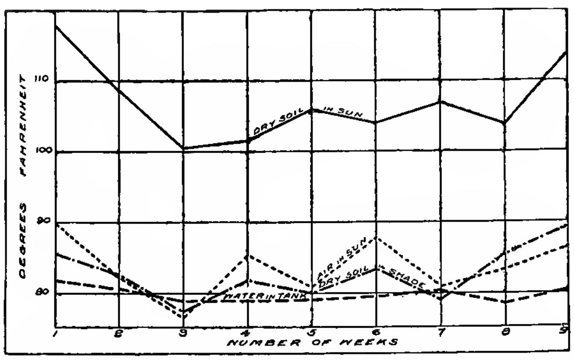
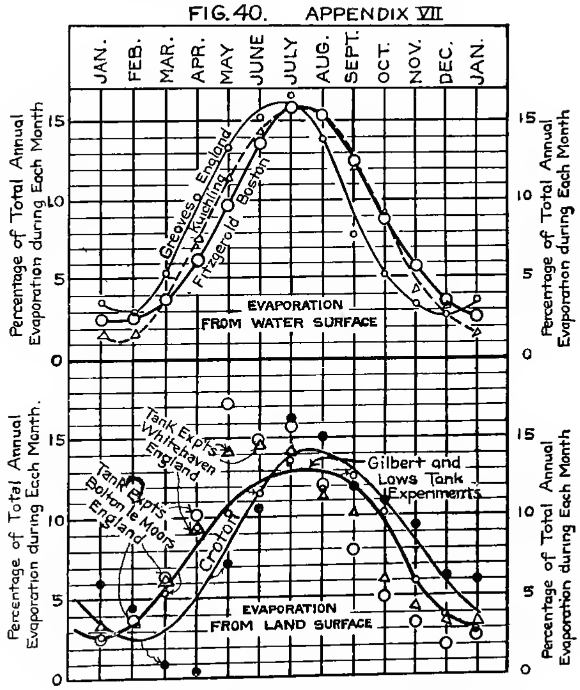


Fig. 18.—Average weekly temperatures for nine consecutive weeks.

The capacity of the soil to absorb heat is further brought out in the report on "New York's Water Supply" by Messrs. Burr, Hering and Freeman, which says on page 764:

"In Fig. 40 the proportion of the total annual evaporation that occurs in each month has been plotted from the evaporation experiments and stream flow; in addition, Fitzgerald's curve of mean monthly evaporation from a water surface and the mean monthly air temperature have been added. Naturally the English experiments do not agree with the curves of evaporation computed from our American streams, because of the difference in the seasons, but the similarity of the curves of evaporation clearly indicate that the monthy evaporation from soil is roughly proportional, like that from a water surface, to the mean monthly temperature of the air.

FIG. 40. APPENDIX VII



SEASONAL DISTRIBUTION OF EVAPORATION FROM WATER AND LAND SURFACES.

"That a greater proportion of the evaporation should occur in the summer is very natural, for evaporation is due to molecular activity at a water surface, and this activity depends upon the amount of heat energy that exists, which is, of course, measured by the temperature of the air and of the surface soil. The soil temperature follows closely that of the air; this was brought out by a good series of soil temperature observations made at Albany from May, 1847, to December, 1848 (Natural History of New York,

1848), which are shown in Fig 40a, together with the mean monthly air temperature in New York City for thirty years."

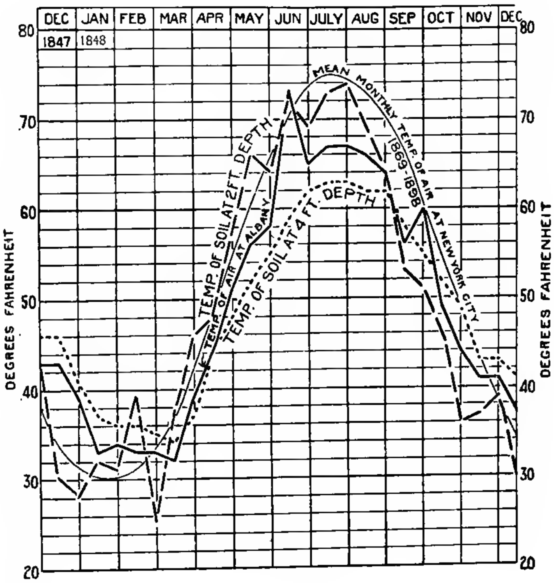


FIG. 40A. APP. VII.
SEMI-MONTHLY OBSERVATIONS ON THE MEAN TEMPERATURE OF THE SOIL AT ALBANY NEW YORK IN 1848.

TRANSPIRATION FROM VEGETATION.

Transpiration from plant life is varied depending largely upon the habitat of the plant. Those species that are common to arid regions use a very small amount of water and have very small transpiration, while plants common to regions of abundant water are so constructed that they utilize and transpire a great deal. A wide range of data on plant transpiration has been obtained by various botanists, but most of it does not deal with the quantitative amount transpired. The Germans have done considerable work along this line. Of their work the Report of the Commission on Additional Water Supply for the City of New York, by Burr, Hering and Freeman says (pages 760, 761, 762):

> The amount of water required by vegetation has been estimated by many experimenters. The best known estimates are perhaps those of Resler, in Germany, which are as follows:

Crop	Consumption of water in inches per day
Meadow Grass	0.134 to 0.267
Oats	0.140 to 0.193
Indian Corn	0.110 to 0.157
Clover	0.140 to .....
Vineyard	0.035 to 0.031
Wheat	0.106 to 0.110
Rye	0.091 to .....
Potatoes	0.038 to 0.055
Oak Trees	0.038 to 0.035
Fir Trees	0.020 to 0.043

> This indicates that anywhere 10 to 30 inches of rainfall each season, will be absorbed by vegetation and even greater quantities when supplied.
>
> The experiments of Prof. King at Madison, Wisconsin, on the amounts of water required to produce a pound of dry matter show that when an ample supply of water is furnished, some crops will absorb as much as 25 inches of water during the growing season. An abundant supply of water is not, however, always present under field conditions and, on an average, cultivated areas probably dissipate 12 to 15 inches of water between May and September. * * *
>
> From the experiments of Dr. Ebermayer and those of Schubler, Harrington has deduced the following values (Table 15) for the evaporation from different surfaces compared to the evaporation from a water surface and the precipitation during the warm season (May to September).

EVAPORATION FROM VARIOUS KINDS OF VEGETATION.

Review of Forest "Meteorological Observations," A Study Preliminary to the Discussion of Relation of Forests to Climate, Harrington.

	Proportion of evaporation from free water surface.	Proportion of precipitation.
Sod	1.92	.96
Cereals	1.73	.86
Forest	1.51	.75
Mixed, etc	1.44	.72
Bare soil	.60	.30

Experiments showing transpiration from wheat and barley were carried on at Tulare, California, from 1903 to 1905 and are published in U. S. Department of Agriculture's Bulletin No. 177. Twelve and seventeen inch in diameter water jacketed tanks, twenty-nine inches deep, were filled with soil in which the grains were planted. These tanks received varying amounts of water and the amount of transpiration was recorded by frequent weighing. The first experiment on wheat was commenced December 11, 1903, and continued until July 14, 1904, when the crops were harvested.

The second experiment started January 12, 1905, and continued until June 22. The yields

from the two sets of experiments together with the amount of water received and the net loss, both in weight and inches, during the season are given in the following tables (Bulletin No. 177, pages 52 and 53):

YIELDS OF WHEAT, TOTAL WATER RECEIVED, AND WATER LOST BY EVAPORATION AND TRANSPIRED AND USED BY CROP IN TULARE WHEAT EXPERIMENT, 1903-4.

Numbers of tanks.	Total water received, pounds.	Total net loss during season, pounds.	Yield of grain, grams.	*Inches water Received.	Used.
1 and 2..	57.27	79.77	0.0	6.28	8.9
3	93.75	113.75	10.0	10.28	12.6
4	128.49	147.49	14.0	14.28	16.5
5	161.49	186.49	19.0	18.28	20.8
6 and 7..	199.71	216.71	38.0	22.28	24.2
19 and 20a	75.51	69.76	....	8.40	7.8

a—Bare soil.

YIELDS OF WHEAT IN TANKS 2 AND 7, AT TULARE, JANUARY 11 TO JUNE 22, 1905, WITH AMOUNTS OF WATER RECEIVED.

Numbers of tanks.	Total water received. Pounds.	Inches.	Loss, pounds.	Yield of grain, grams.	*Loss, inches.
2 and 3..	110.08	12.07	136.58	11.2	14.9
4 and 5..	164.80	18.07	190.30	33.6	20.8
6 and 7..	246.88	27.07	254.68	16.6	27.8
1 and 21a	97.53	10.69	92.60	....	10.1

a—Bare soil.

*In the U. S. Bulletin the quantity of water is given in pounds. For convenience of comparison this quantity reduced to inches is given in the starred columns in the above tables, and also in tables which follow.

These results show that the total loss by evaporation and transpiration was between two and three times the loss from bare soil.

Similar experiments with barley were carried on simultaneously with the wheat experiments, using 17-inch diameter water jacketed tanks instead of 12-inch ones. The first experiment began on December 11, 1903, and the losses as well as the total amounts of water received by each tank and the yields of grain are given in the following summary (Bulletin 177, page 55):

YIELDS OF BARLEY, TOTAL WATER RECEIVED, AND LOSS BY EVAPORATION AND AMOUNT OF WATER TRANSPIRED AND USED BY CROP IN TULARE BARLEY EXPERIMENT, 1903-4.

Numbers of tanks	Total water received, pounds.	Total net loss during season, pounds.	Yield of grain, grams.	*Inches water. Received.	Used.
21 and 22.	57.27	78.27	27	6.28	8.58
23	93.75	107.75	41	10.28	12.00
24	128.49	148.49	62	14.28	16.70
25	161.49	170.49	48	18.28	19.10
26 and 27.	198.71	198.96	66	22.28	22.20
17 and 18.	75.51	78.01	..	8.40	8.70

Of this experiment the Bulletin says (page 54):

"When the experiment was terminated and the soils turned out of the tanks, that in Nos. 21 and 22, which received no irrigation water, was very dry. Roots had accumulated in the bottom of the tanks in their search for what moisture the soil contained. The bare tanks, 17 and 18, were fairly moist up to within 4 to 6 inches of the surface. In Nos. 26 and 27, which received the most water—16 inches in addition to rainfall—the surface was dry, but the bottom layers were quite moist."

This experiment shows that the transpiration from barley was as much as 2½ times the evaporation from bare soil.

Experiments carried on by the U. S. Experiment Station at Berkeley, California, on the common Portuguese or horse bean to determine the effect of varying amounts of water show interesting results.

Seventeen-inch diameter water jacketed tanks, 29 inches deep containing graded soils were used. In the first experiment the seed was planted Sept. 1, 1904, one tank in seven being left bare and various amounts of water being supplied in addition to the natural rainfall.

The first experiment expired Feb. 8, 1905, and the second one began March 8, 1905, and continued until August 8, 1905. In the tabulated summary below are given the amounts of water applied to and evaporated from the uncropped tanks and the yield from the cropped tanks are included (Bulletin 177, page 59):

COMPARISON OF AMOUNTS OF WATER APPLIED TO HORSE BEANS, WITH THE AMOUNTS LOST BY EVAPORATION AND TRANSPIRED BY THE PLANTS.

*First experiment. Total water, in inches. Received.	Loss.	Numbers of tanks.	First experiment. Total water received, pounds.	Total net loss during experiment, pounds.	Yield of green matter, grams.	Second experiment. Total water received, pounds.	Total net loss during experiment, pounds.	Yield of green matter, grams.	*Second experiment. Total water in inches. Received.	Loss.
20.10	15.9	1 and 2........	67.50	132.87	3,352	89.60	113.72	404	10.73	13.6
24.10	18.7	3 and 4........	99.85	155.22	4,281	223.20	240.57	1,386	26.73	29.0
33.50	29.0	5 and 6........	276.25	240.50	4,547	321.81	316.31	2,095	38.46	38.0
11.00	5.0	7	92.00	42.25	.....	131.35	95.85	.....	15.75	11.5

Speaking of the first experiment the Bulletin says (page 57):

> "Although tank No. 7, which was bare, received only one inch of irrigation water, the heavy rains kept it so saturated throughout the term of the experiment, and at various times sufficient standing water was removed from the surface to make a total depth so removed for the season of nine inches. At one time, before the plants had made much growth, it was also necessary to remove about two inches each from the four irrigated tanks."

The results as given in the tabulation above show that in the first experiment the tanks which did the best and the one which received the most water transpired five times as much as evaporated from the bare soil, and that the total evaporation and transpiration from these tanks (5 and 6) in the first experiment was 29 inches, as against a water surface evaporation of 11.58 inches. The second experiment shows a loss by transpiration of 26.5 inches from tanks 5 and 6 while the loss from bare soil was 11.5 inches. The total loss from tanks 5 and 6 was 38 inches, as against a water surface evaporation of 21 inches, or nearly twice water surface evaporation during the spring and summer months.

In regard to Owens River Valley experiments Mr. C. H. Lee writes:

> "Actual measurements on alfalfa in Owens Valley shows the depth of transpiration from blooming plants to be 0.49 inches per 24 hours on a day when the depth of water evaporating from a pan floating in Owens River was 0.30 inches."

This experiment was made by cutting the alfalfa and weighing it at frequent intervals, and it does not include the loss from the soil.

Mr. Lee further writes:

> "The evaporation from soil growing salt grasses when the water stands near the surface is 1.15 times that from a free water surface during the summer months and 45% during the winter."

In his experiments Mr. Lee considered the winter as from Oct. 1 to March 31. In Livermore Valley the wild grasses grow practically all winter and we take salt grass evaporation as 90% during that period.

Many measurements have been made on transpiration per square inch of leaf surface and it has been found to vary from 26 to 45% of water surface evaporation. The Burr, Hering and Freeman Report on "New York's Water Supply" says (page 761):

> "The amount of water that is transpired by leaf surfaces has been estimated by Unger to be 33 per cent of the evaporation from an equivalent water surface (or perhaps 30 per cent of the rainfall); Sachs found 36 per cent of evaporation from equivalent water surface for white poplar and 42% for sunflower."

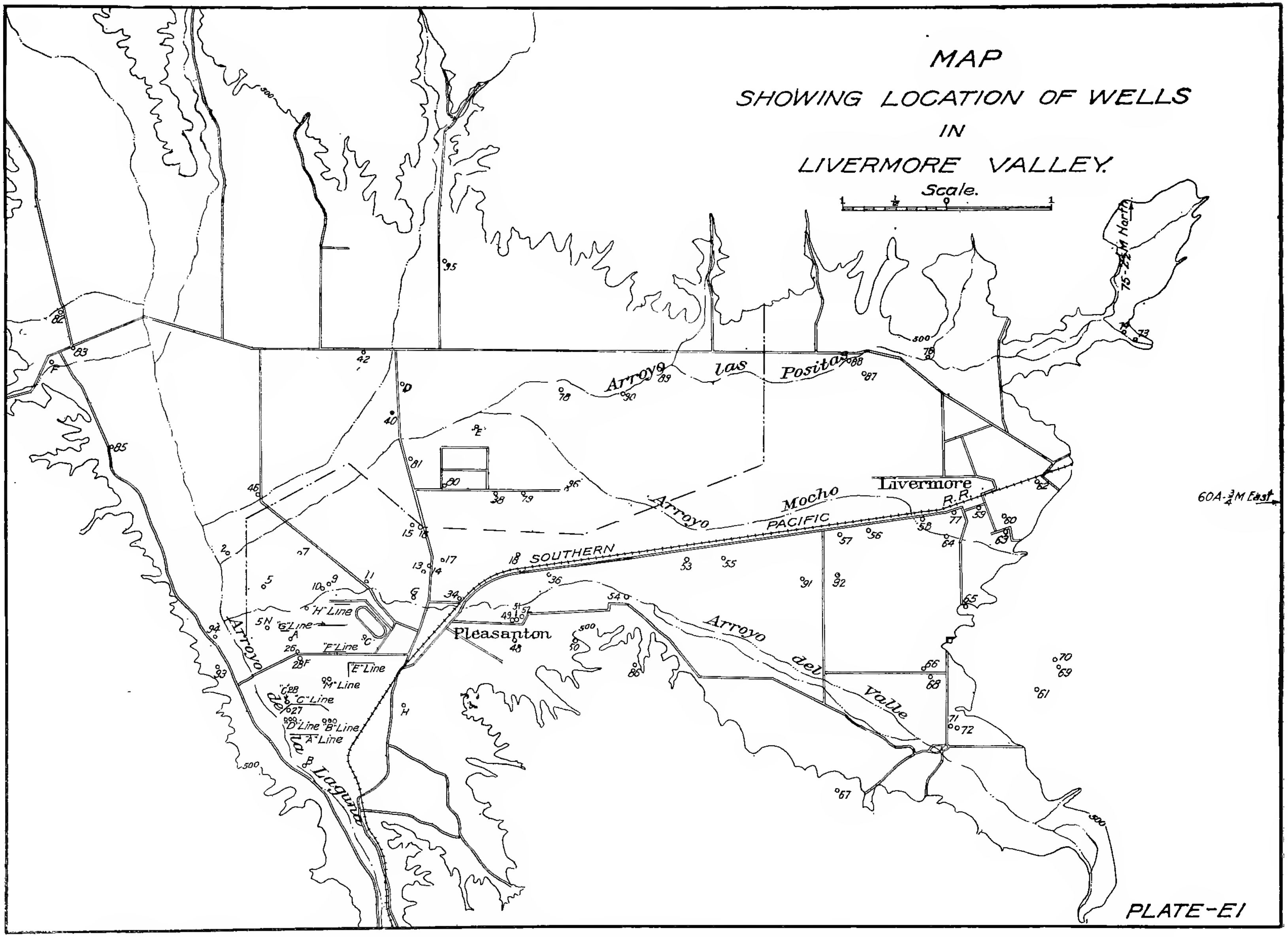
As the leaf surface of plants is many times larger than ground surface which they cover, the above estimates indicate that plant transpiration over any given area is very much greater than water surface evaporation of an equivalent area.

Authorities state that crops in general use from 400 to 600 times their weight in water. The U. S. Department of Agriculture made experiments on sugar beets in Colorado and found that a very inferior crop of beets during their growth transpired more than 500 times their weight of water. This does not include the evaporation from the soil. A good crop of beets which is now extensively raised on the former saturated area of Livermore Valley will net more than 15 tons of beets per acre. Five hundred times these 15 tons is 7500 tons of water per acre, equal to a depth of 66 inches of water transpired in the growing season of 6 months between February and August.

CONCLUSIONS.

In view of the above given data and all data obtainable we are justified in assuming that:

1. The evaporation from the area of the Livermore Valley formerly saturated and supporting a dense growth of tules, willows and wild celery, etc., was at least 66 inches per annum, and that under the present crop conditions the evaporation over this area is at least that much per annum.
2. That over the area supporting salt grass and other wild grasses the evaporation is proportional to the depth of water table, being at least 52 inches when the water table is near the surface.
3. That the water loss by evaporation applicable to large water bodies in Alameda County averages 48 inches per annum, which in its application to the gross draft should be reduced by that portion of the rainfall over the surface of the reservoir not included in the run-off.



LOGS OF WELLS THROUGHOUT THE LIVERMORE VALLEY WERE USED IN THE STUDY OF THE GEOLOGY.

Appendix E.

LOGS OF WELLS IN THE LIVERMORE VALLEY

Plate No. E-1

Well No. 15—Line "A."

Material.	Depth, feet.
14-inch pipe is 19 feet deep.	
Soil	4
Yellow sandy clay	11
Blue clay	4
Blue clay	6
Yellow clay	15
Blue clay	12
Blue gravel	4
Gravel	12
Blue clay	2
Bottom well 70 feet deep.	
Pipe cut from 68 to 55 feet.	

Well No. 2—Line "D."

14-inch pipe is 20 feet deep.	
Soil	4
Blue clay	34
Yellow clay	4
Tight gravel	17
Yellow clay	1
Well 60 feet deep.	
Pipe cut from 58 to 45 feet.	

Well No. 6—Line "D."

14-inch pipe is 21 feet deep.	
Soil	5
Yellow clay	14
Blue clay	8
Blue clay	20
Blue clay and gravel mixed	9
Gravel	4
Gravel	2
Yellow clay	2
Bottom of well 64 feet deep.	
Pipe is cut from 62 to 50 feet.	

Well No. 16—Line "A."

Material.	Depth, feet.
14-inch pipe is 22 feet deep.	
Soil	5
Blue clay	5
Blue clay	32
Blue sandy clay	16
Blue gravel	13
Blue gravel	1
Soft blue clay	15
Soft blue sandy clay	10
Blue sandy clay	3
Well finished at 100 feet deep.	
Pipe cut from 72 to 58 feet.	

Well No. 13—Line "A."

14-inch pipe is 15 feet deep.	
Soil	4
Blue sandy clay	6
Blue clay	16
Yellow clay	6
Blue sandy gravel	4
Sand and gravel	16
Sand and gravel	8
Gravel	2
Gravel	4
Hard blue clay finished	1
Pipe is cut from 66 to 50 feet.	

Well No. 1—Line "B."

14-inch pipe is 12 feet deep.	
Black bog	4
Blue clay	6
Yellow clay	5
Blue clay	4
Yellow clay	11
Sand and gravel	5
Yellow sand	5
Coarse gravel	12
Cemented sand	2
Well finished at 54 feet.	
Pipe is cut from 53 to 47 feet.	

Well No. 10.

(Under flow Sta. No. 2.)

Material.	Depth, feet.
Sand loam	4
Heavy loam	$3\frac{1}{2}$
Sandy loam	$4\frac{3}{4}$
Fine gravel	$\frac{3}{4}$
Blue clay, changing to	46
Yellow sandy clay	3
Gravel	7
(At bottom of clay, coarse gravel is very tightly imbedded, forming almost hardpan. This changes to a med. gravel.)	

Well No. 17.

(Test well.)

Top soil	6
Light, sandy clay	38
Hard bed clay and gravel	1
Hardpan and coarse gravel	

Well No. 18.

Pit—surf. soil	27
Gravel	24
Yellow sand clay	9
Cement gravel	8
Yellow sand clay	1
Gravel	4
Yellow sand clay	5
Gravel	5
Yellow sand clay	5
Cement gravel	2
Yellow sand clay	4
Gravel	6
Yellow sand clay	2
Gravel	4
Yellow sand clay	1
Hard cement gravel	$44\frac{1}{2}$

Well No. 26.

(Test well by S. V. W. Co.)

Surface soil	8
Gravel and sand	$\frac{3}{4}$
Blue clay	$41\frac{1}{4}$
Artesian gravel	6

Well No. 40.

Soil	3
Sand	7
Clay	39
Gravel	14

Well No. 42.

Material.	Depth, feet.
Soil	5
Sand (little water)	1
Gray to blue, clay	8
Blue clay	7
Gray clay	13
Yellow sediment	10
Blue clay and sand	3
Blue clay and gravel	4
Coarse water gravel	17
Fine gravel and sand	13
Yellow clay	10
Blue clay, somewhat sandy	5
Clay (blue to gray)	2
Gray, sandy clay, mostly sand	7
Blue clay	
(Total depth, 130 feet.)	

Well No. 46.

(Test well.)

Blue clay	8
Sand and gravel	1
Blue clay	34
Yellow clay	$3\frac{1}{2}$
Gravel	

Well A.

(At present Spring Valley W. Co.)

Soil	7
Quicksand	2
Gray clay	37

Well B.

(At present S. V. W. Co.)

Soil	4
Blue clay	43

Well 28—Line "C."

14-inch pipe is 24 feet deep.

Soil	3
Gray clay	7
Yellow clay	10
Blue clay	19
Yellow clay	5
Gravel	7
Gravel	7
Blue cemented clay	10

Well 27—Line "C."

14-inch pipe is 24 feet deep.

Soil	3
Blue clay	21
Blue clay	16
Yellow clay	2
Gravel	4

Material.	Depth, feet.
Gravel clay	5
Blue gravel	6
Blue cemented clay	10
Blue cemented clay	3

Well finished at 70 feet.
Pipe cut from 57 to 44 feet.
Flow decreased after passing 51 feet.

Well No. 24—Line "C."

14-inch pipe is 24 feet deep.

Soil	3
Gray clay	31
Yellow clay	7
Fine sand	3
Gravel	43
Yellow clay	3
Yellow clay	3
Gray clay	4

Well finished at 97 feet.
Pipe cut from 85 to 45 feet.

Well 23½—Line "C."

14-inch pipe is 30 feet deep.

Soil	6
Blue clay	11
Blue clay	13
Blue clay	8
Gravel	13
Gravel	3
Hard gray clay	6

Well finished at 60 feet.
Pipe cut from 54 to 38 feet.

Well 25—Line "C."

14-inch pipe is 24½ feet deep.

Black soil	3
Gray clay	12
Gray clay	20
Yellow clay	5
Yellow clay	6
Gravel	13
Gravel	1
Hard blue clay	15

Well is finished at 75 feet.
Pipe is cut from 60 to 45 feet.

Well 24½—Line "C."

14-inch pipe is 30 feet deep.

Soil	6
Blue clay	24
Blue clay	12
Gravel	13

Material.	Depth, feet.
Yellow clay	4
Hard blue clay	6

Pipe is cut from 55 to 42 feet.

Well 21½—Line "C."

14-inch pipe is 28 feet deep.

Black soil	6
Blue clay	14
Blue clay	16
Yellow clay	3
Gravel	22
Cemented gravel	11
Cemented gravel	1
Clean gravel	4
Yellow clay	4

Well finished at 81 feet.
Pipe cut from 75 to 45 feet.

Well 20½—Line "C."

14-inch pipe is 28 feet deep.

Soil	6
Blue clay	10
Blue clay	21
Yellow clay	2
Clean gravel	17
Clean gravel	9
Hard yellow clay	5

Well finished at 70 feet.
Pipe cut from 65 to 45 feet.

Well 23½—Line "C."

14-inch pipe is 30 feet deep.

Soil	6
Blue clay	11
Blue clay	13

Well 23—Line "C."

14-inch pipe is 25 feet deep.

Black soil	2
Gray clay	32
Yellow clay	7
Fine gravel	16
Cemented gravel	7
Cemented yellow clay	21
Yellow clay	9
Blue clay	12

Well finished at 106 feet.
Pipe is cut from 57 to 41 feet.

Well 22½—Line "C."

14-inch pipe is 28 feet deep.

Soil	6

Material.	Depth, feet.
Yellow sandy clay	6
Blue clay	16
Blue clay	9
Clean gravel	19
Clean gravel	1
Blue clay	6

Well finished at 63 feet.
Pipe cut from 57 to 45 feet.

Well 19½—Line "C."

14-inch pipe is 30 feet deep.

Soil	6
Blue clay	24
Blue clay	13
Coarse gravel	11
Coarse gravel	3
Yellow clay	5
Blue clay	10

Pipe will be cut from 55 to 43 feet.

Well 20—Line "C."

14-inch pipe is 16 feet deep.

Black soil	5
Yellow soil	3
Yellow clay	4
Blue clay	18
Blue clay	6
Yellow clay	6
Fine gravel	20
Gravel	5
Yellow clay	2

Bottom of well at 67 feet.
Pipe cut from 64 to 43 feet.

Well No. 22—Line "C."

14-inch pipe is 16 feet deep.

Black soil	4
Gray sandy clay	6
Blue clay	4
Blue clay	20
Yellow clay	5
Gravel	12
Gravel	5
Yellow clay	2

Bottom of well at 57 feet.
Pipe cut from 55 to 43 feet.

Well 15—Line "C."

Gray clay	4

14-inch pipe is 24 feet.

Material.	Depth, feet.
Soil	7
Fine gravel	7
Gray clay	27
Gray clay	1
Yellow clay	3
Coarse gravel	13
Coarse gravel	9
Yellow clay	4
Yellow clay	4

Pipe is cut from 71 to 53 feet.

Well 17—Line "C"

14-inch pipe is 23 feet deep.

Soil	9
Coarse sand	3
Gray clay	11
Gray clay	19
Yellow clay	3
Gravel clay	4
Gravel clay	22
Gravel clay	5
Cemented gravel	6
Gravel	8
Clean gravel	11
Clean gravel	11
Clean gravel	13
Hard yellow clay.	5

Pipe is cut from 113 to 100 and from 70 to 48 feet.

Well No. 16—Line "C"

14-inch pipe is 28 feet deep.

Black soil	3
Black sand	3
Sandy gravel	10
Yellow clay	5
Blue clay	11
Blue clay	11
Yellow clay	4
Gravel	13
Gravel	20
Gravel	8
Yellow clay	2

Well is finished at 90 feet deep.
Pipe is cut from 80 to 50 feet.

Well No. 18—Line "C"

14-inch pipe is 20 feet deep.

Black soil	3
Black sandy clay	3
Yellow sand	1
Gray sandy clay	9
Blue clay	28
Sandy gravel	4
Loose gravel	15

Material.	Depth, feet.
Hard gravel	7
Hard gravel	12
Tight gravel	9
Yellow clay	1

Well finished at 92 feet deep.
Pipe is cut from 90 to 46 feet.

Well No. 13—Line "C"

14-inch pipe is 18 feet deep.

Soil	3
Yellow clay	12
Blue clay	3
Blue clay	12
Yellow clay	13
Gravel	5
Gravel	16
Gravel	1
Mixed clay	5

Well finished at 70 feet deep.
Pipe is cut from 65 to 45 feet.

Well No. 4—Line "C"

14-inch pipe is 15 feet deep.

Soil	1
Blue clay	14
Yellow clay	5
Blue clay	12
Blue clay	3
Gravel	23
Coarse clay	6
Yellow clay	2

Well is finished at 66 feet deep.
Pipe is cut from 62 to 40 feet.

Well No. 12—Line "C."

14-inch pipe is 12 feet deep—not finished.

Soil	5
Yellow sandy clay	4
Yellow clay	1
Yellow sandy clay (14-inch pipe 25 feet deep)	2
Gray sandy clay	34
Blue sandy clay	3½
Yellow clay	½
Gravel	13
Yellow clay	2

Well is finished 65 feet deep.
Pipe is cut from 63 to 51 feet.

Well No. 14—Line "C"

14-inch pipe is 15 feet deep.

Material.	Depth, feet.
Adobe	4
Yellow sandy clay	7
Light blue clay	5
Yellow clay	24
Yellow clay	7
Gravel	17
Yellow clay	4

Well is finished at 68 feet.
Pipe is cut from 64 to 57 feet.

Well No. 10—Line "C"

14-inch pipe is 13 feet deep.

Soil	5
Yellow sand	3
Sand clay	2½
Mixed clay	1½
Dark gray clay	5
Sandy clay	23
Gravel	12
Gravel	12
Yellow clay	2
Blue clay	1

Well is finished at 67 feet.
Pipe is cut from 64 to 50 feet.

Well No. 9—Line "C"

14-inch pipe is 16 feet deep.

Soil	2
Blue clay	4
Yellow clay	4
Blue clay	11
Yellow clay	12
Yellow clay	2
Gravel	24
Gravel	3
Yellow clay	2

Well is finished at 64 feet deep.
Pipe is cut from 62 to 42 feet.

Well No. 11—Line "C"

14-inch pipe is 16 feet deep.

Soil	2
Blue clay	3
Yellow clay	8
Blue clay	27
Blue clay	8
Gravel	12
Yellow clay	3

Well No. 7—Line "C"

14-inch pipe is 15 feet deep.

Soil	2
Blue clay	6

Material.	Depth, feet.
Very fine gravel	3
Blue clay	20
Blue clay	2
Loose gravel	12
Tight gravel	10
Tight gravel	6
Yellow clay	2

Well finished at 63 feet deep.
Pipe is cut from 61 to 45 feet.

Well No. 21—Line "C"

14-inch pipe is 20 feet deep.

Soil	2
Yellow clay	10
Blue clay	22
Yellow clay	3
Yellow clay	6
Gravel	12
Yellow clay	3

Well finished at 58 feet deep.
Pipe is cut from 51 to 45 feet.

Well No. 6—Line "C"

14-inch pipe is 12 feet deep.

Blue clay	5
Sandy clay	5
Blue clay	4
Gravel	7
Sandy clay	2
Blue clay	2
Dirty sand	21
Gravel	17
Yellow clay	3

Well is finished at 66 feet.
Pipe is cut from 61 to 41 feet.

Well No. 8—Line "C"

14-inch pipe is 13 feet deep.

Soil	2
Blue clay	14
Mixed clay	18
Sand and gravel	18
Gravel	10
Yellow clay	1
Blue clay	1

Well is finished at 64 feet.
Pipe is cut from 62 to 40 feet.

Well No. 5½—Line "C"

14-inch pipe is 12 feet deep.

Material.	Depth, feet.
Soil	2
Yellow clay	7
Blue clay	6
Yellow clay	10
Yellow clay	7
Gravel	12
Coarse sand	6
Gravel	3
Gravel	3
Yellow clay	3

Well finished at 59 feet.
Pipe is cut from 56 feet to 50 feet.
Pipe is cut from 44 feet to 32 feet.

Well No. 19—Line "C"

14-inch pipe is 17 feet deep.

Soil	4
Yellow sandy clay	11
Blue clay	3
Gray clay	21
Yellow sandy clay	4
Sand and gravel	2
Coarse cemented gravel	4
Loose gravel	5
Tight gravel	2
Loose gravel	6
Gravel and clay mixed	2
Loose sand and gravel	6
Gravel and clay mixed	1
Yellow clay	1
Sand and gravel	2
Clay and gravel mixed	3
Yellow clay	1

Well finished at 76 feet.
Pipe cut from 60 to 54 feet.
From 68 and 70 to 72 feet.

Well No. 5—Line "C"

14-inch pipe is 12 feet deep.

Soil and roots	2
Blue clay	10
Yellow clay	3
Yellow clay	10
Sand and gravel	21
Yellow clay	1
Blue clay	1

Bottom of well at 56 feet deep.
Pipe cut from 54 to 40.

Well No. 1—Line "C"

14-inch pipe is 15 feet deep.

Soil and roots	8
Blue clay	3
Blue sandy clay	3

Material.	Depth, feet.
Yellow sandy clay	9
Sand and gravel	19
Sand and gravel	3
Coarse gravel	5
Yellow sand	1
Gravel	6
Yellow clay	13

Well is finished at 70 feet.

Pipe is cut from 56 to 54½ feet and from 53 to 51½ feet.

Well No. 3—Line "C"

14-inch pipe 9 feet deep.

Black bog	2
Blue clay	8
Yellow clay	18
Yellow sand	6
Gravel	6
Gravel	11
Yellow clay	3

Well is finished at 54 feet deep.

Pipe cut from 50 to 38 feet.

Well No. 8—Line "D"

14-inch pipe is 26 feet deep.

Soil	4
Blue sand	4
Blue sandy gravel	2
Blue clay	2
Blue sandy gravel	8
Yellow sand	2
Blue sandy clay	2
Blue clay	2
Blue clay	4
Gray clay	4
Blue clay	14
Yellow clay	2
Yellow sand	1
Gravel	9
Gravel	3
Yellow clay	1
Blue cement gravel	8
Hard blue cement and gravel	8
Hard blue cement and gravel	5

Well finished at 85 feet.

Pipe is cut from 63 to 52.

Well No. 4—Line "D"

14-inch pipe is 20 feet deep.

Material.	Depth, feet.
Soil	3
Blue clay	5
Yellow clay	9
Blue clay	13
Blue clay	11
Yellow clay	3
Gravel	16
Yellow clay	3

Well is 65 feet deep.

Well No. 1—Line "D"

14-inch pipe is 20 feet deep.

Soil	4
Blue clay	4
Yellow sandy clay	1
Blue clay	2
Gray and blue clay mixed	29
Yellow clay	4
Gravel	5
Coarse tight gravel	14
Yellow clay	1

Well finished at 64 feet deep.

Pipe cut from 62 to 46 feet.

Well No. 10—Line "E"

14-inch pipe is 14 feet deep.

Soil	3
Light blue clay	30
Yellow clay	9
Yellow gravel and clay mixed	16
Yellow gravel and clay mixed	2

Well finished at 60 feet deep.

Pipe not cut.

Well No. 16—Line "E"

14-inch pipe 20 feet deep.

Soil	5
Yellow clay	22
Gravel	8
Hard tight gravel	8
Gravel	1½
Gravel and clay	5½
Gravel	3
Hard cement clay	5

Finished at 58 feet.

Pipe not cut.

Well No. 7—Line "E"

14-inch pipe is 20 feet deep.

Soil	4
Blue sand	3
Yellow sandy clay	4
Yellow sand	5
Fine sand and gravel	12

Material.	Depth, feet.
Gravel	4
Gravel	5½
Yellow clay	30½
Tight gravel	23
Yellow clay	2

Well finished at 93 feet.

Pipe is cut from 91 to 71 and 37 to 28 feet.

Well No. 2—Line "E"

14-inch pipe is 15 feet deep.

Soil	2
Yellow clay	11
Blue clay	4
Yellow clay	5
Blue clay	6
Yellow clay	12
Yellow sand	2
Gravel	9
Yellow sand	3
Gravel	8
Gravel	1
Yellow clay	3

Well finished at 66 feet deep.

Pipe is cut from 63 to 54 feet and from 51 to 42 feet.

Well No. 4—Line "E"

14-inch pipe is 17 feet deep.

Soil	2
Adobe	3
Yellow sandy clay	5
Yellow clay	4
Yellow clay	8
Gravel	13
Gravel	2
Yellow sandy clay	15
Dirty yellow gravel	4
Gravel	1
Yellow clay	3

Well is finished at 60 feet deep.

Pipe cut from 37 to 22 feet.

Well No. 5—Line "E"

14-inch pipe is 15 feet deep.

Soil	2
Blue clay	6
Yellow clay	4
Yellow clay	10
Gravel	8
Gravel	5
Yellow clay	27

Material.	Depth, feet.

Well No. 1—Line "E"

Soil	1
Black adobe	4
Yellow sandy clay	10
Yellow clay	2
Gravel	4
Yellow clay	20
Gravel	5
Loose Gravel	8
Tight gravel	6
Gravel	2
Yellow clay	2

Well finished at 64 feet.

Pipe is cut from 62 to 42 feet.

Well No. 3—Line "E"

14-inch pipe is 18 feet deep.

Soil	2
Yellow clay	12
Blue clay	11
Blue clay	5
Yellow clay	2
Gravel	3
Yellow clay	8
Gravel	10
Gravel	9
Yellow clay	3

Well finished at 65 feet.

Pipe is cut from 52 to 43 feet.

Well No. 15—Line "F"

Coarse gravel	2
Fine gravel and sand	3
Gravel	3
Mixed clay gravel	1
Yellow clay	3
Blue clay	8
Blue light clay	5
Yellow clay	4

Well finished at 141 feet.

Pipe not cut.

Well No. 8—Line "F"

Soil	5
Gravel	4
Gravel	6
Clay	4
Sand	3
Clay	3
Blue clay	6
Yellow clay	9

Material.	Depth, feet.
Sandy clay	7
Sand	4
Gravel	6
Clay	2
Gravel	6
Yellow clay	10
Blue clay	3
Gravel	9
Sand	8
Gravel	3
Yellow clay	10
Hard sand	6
Gravel	2
Gravel	10
Yellow clay	4

Well finished at 130 feet.
Pipe not cut.

Well No. 1—Line "F"

Yellow clay	2
Clay and gravel mixed	3
Cement clay	1
Clean gravel	6
Clean gravel	7
Clean coarse gravel	4
Coarse sand	3
Coarse gravel	6
Coarse gravel	3
Yellow clay	3
Hard gray clay	12
Yellow cemented clay	3
Gravel	5
Gravel	1
Yellow clay	7
Hard gray clay	7
Hard gray clay	8

10-inch pipe is 3 feet above ground surface. Water is 1½ feet below top of 10-inch casing.

Well No. 8—Line "F"

14-inch pipe is 19 feet deep.

Soil	5
Gravel	4
Gravel	6
Clay	4
Sand	3
Clay	3
Blue clay	6
Yellow clay	9
Sandy clay	7

Material.	Depth, feet.
Sand	4
Gravel	6
Clay	2
Gravel	6
Yellow clay	10
Blue clay	3
Sand	8
Gravel	3
Yellow clay	10
Hard sand	6
Gravel	2
Gravel	2
Yellow clay	4

Well finished at 130 feet.

Well No. 28—Line "F"

14-inch pipe is 29 feet deep.

Soil	19
Fine gravel	5
Gray clay	26
Blue clay	2
Yellow clay	5
Gravel and rock	45
Hard gray clay	9
Yellow sandy clay	2
Fine sand and gravel	18
Blue clay	15

Well No. 1—Line "F"

14-inch pipe is 20 feet deep.

Soil	3
Dark clay	17
Yellow clay	28
Sand and gravel	5
Gravel	2
Yellow clay	10

Well finished at 65 feet.
Pipe not cut.

Well No. 39—Line "G"

Soil	2
Fine gravel	14
Hard gray clay	24
Hard gray clay	44

Well No. 37—Line "G"

14-inch pipe is 27 feet deep.

Soil	2
Gravel	13
Gray clay	30
Sand	5
Gray clay	17

Material.	Depth, feet.
Yellow clay	4
Sand	4
Gravel	10
Coarse sand	7
Coarse gravel	16
Blue clay	10
Gravel	18
Hard yellow clay	8
Hard yellow clay	3
Hard blue clay	13

Well No. 22—Line "F"

14-inch pipe is 30 feet deep.

Soil	2
Fine sand and gravel	12
Fine sand and gravel	8
Blue clay	3
Blue clay	31
Coarse gravel	1
Very coarse gravel	9
Coarse gravel	8
Coarse gravel	9
Coarse gravel	5
Yellow clay	5
Blue clay	10
Blue clay	1
Coarse gravel	9
Coarse gravel	1
Yellow clay	5
Blue clay	19

Pipe not cut.

Well No. 15—Line "F"

14-inch pipe is 22 feet deep.

Light loam	4
Dark loam	2
Light sandy clay	13
Dark clay	3
Sandy clay	3
Blue clay	5
Gray sandy clay	18
Dark yellow clay	3
Yellow sandy ground	4
Gravel	3
Coarse gravel	2
Gravel coarse rock	6
Clay and gravel mixed	2½
Coarse gravel	11½
Fine gravel	2
Clay and gravel	1
Tight gravel	3

Material.	Depth, feet.
Clay and gravel mixed	1
Clean gravel	3
Clay and gravel mixed	1
Yellow clay	2
Clay and gravel mixed	1
Gravel	3
Clay and gravel mixed	1
Clean gravel	5
Clay and gravel	1
Gravel	8

Well No. 29—Line "G"

14-inch pipe is 22 feet deep.

Soil	12
Tough gray clay	4
Tough gray clay	23
Sand	4
Blue clay	6
Blue clay	3
Yellow clay	9
Blue clay	3
Yellow clay	3
Gravel	6
Gravel	18
Gravel	10
Yellow clay	3
Blue clay	1
Blue clay	3
Yellow clay	3
Coarse gravel	5
Coarse gravel	6
Clay and gravel mixed	6
Hard yellow clay	6
Hard yellow clay	8
Hard gray clay	8
Hard gray clay	14
Hard gray clay	10
Yellow clay	2
Hard yellow clay	6

Well finished at 182 feet.

Pipe not cut.

Well No. 13—Line "G"

14-inch pipe is 16 feet deep.

Soil	6
Yellow clay	8
Light blue clay	7
Yellow sandy clay	9
Mixed clay	40
Gravel	17
Gravel	13
Gravel	15

Material.	Depth, feet.
Gravel	13
Gravel	1
Yellow clay	2

Well finished at 131 feet.
Pipe not cut.

Well No. 19—Line "G"

14-inch pipe is 21 feet deep.

Loam	13
Fine gravel	7
Fine gravel	12
Dark gray clay	2
Yellow sandy clay	2
Dark gray clay	2
Gray sandy clay	10
Dark gray sandy clay	1
Gray sandy clay	7
Blue clay	2
Yellow sandy gray clay	4
Light blue clay	3
Light yellow clay	6
Yellow sand	1
Fine gravel	3
Coarse gravel	1
Hard gravel	½
Yellow clay	1
Yellow clay	1
Clay and gravel mixed	1
Gravel	4
Gravel	4
Clay and gravel	2
Tight gravel	3
Tight gravel	10
Tight gravel	6
Yellow clay	1
Yellow gravel and cement	1
Blue clay	2
Blue clay	8
Yellow clay	1
Hard yellow clay	4
Dirty gravel	1
Gravel	13
Gravel	2
Yellow clay	2

Well finished at 145 feet.
Pipe not cut.

Well No. 10—Line "G"

14-inch pipe is 18 feet deep.

Material.	Depth, feet.
Soil	6
Dark clay	10
Yellow clay	6
Dark clay	3
Yellow clay	9
Dark clay	14
Yellow clay	23
Gravel	6
Yellow clay	2
Blue clay	7
Gravel	4
Gravel	16
Gravel	9
Clay	6

Well finished at 121 feet.

Well No. 7—Line "G"

14-inch pipe is 23 feet.
14-inch pipe not cut.

Light soil	7
Dark ground	3
Dark ground	2
Yellow sandy ground	9
Dark clay	3
Dark gray sandy clay	10
Yellow sandy clay	5
Yellow sand	2
Fine loose gravel	3
Hard gravel	1
Yellow clay	1
Gravel	1
Gravel	8
Hard gravel	4
Yellow sand	2½
Gravel	1½
Yellow clay	1
Blue clay	1

Well finished at 65 feet deep.
Pipe not cut.

Blue clay	2
Yellow clay	15
Gravel	20
Gravel	5
Clay	2
Hard cement	1

Well finished at 110 feet.

Well No. 14—Line "G"

14-inch pipe is 22 feet deep.

Dark loam	15
Tough clay	4
Gray clay	23
Sand	3

Material.	Depth, feet.
Gray clay	4
Gray clay	12
Yellow clay	7
Coarse gravel	10
Coarse gravel	9
Coarse gravel	16
Coarse gravel	10
Blue clay	2
Blue clay	17
Blue clay	7
Gravel	3
Gravel	4
Yellow clay	6
Yellow clay	1
Blue clay	4
Blue clay	5

Well No. 1—Line "G"

14-inch pipe is 30 feet deep.

Light loam	4
Dark loam	2
Yellow sandy clay	9
Dark gray clay	15
Gray sandy clay	12
Yellow sandy clay	1
Yellow sand	2
Sand and gravel	2
Gravel	8
Hard tight gravel	12½
Yellow clay	2½

Well finished at 70 feet deep.

Pipe not cut.

Well No. 1—Line "H"

14-inch pipe is 15 feet deep.

Soil	4
Mixed sand	3
Fine gravel	4
Yellow sandy clay	3
Hard yellow clay	2
Soft gray clay	11
Hard gray clay	4
Yellow sandy clay	2
Yellow sand	1
Fine loose gravel	6
Fine loose gravel	6
Coarse gravel	13
Coarse gravel	5½
Yellow clay	1½

Well finished at 66 feet.

Pipe not cut.

Material.	Depth, feet.

Well No. 6—Line "I"

14-inch pipe is 20 feet deep.

Soil	2
Light blue clay	18
Light blue clay	9
Gravel	6
Yellow clay	15
Yellow clay and gravel mixed	10
Clean gravel	5
Clean gravel	10
Gravel	2
Clay	1

Well finished at 78 feet.

Pipe cut from 77 feet to 60 feet.

Well No. 2—Line "I"

14-inch pipe is 20 feet deep.

Soil	1
Black adobe	4
Yellow clay	11
Yellow clay	28
Gravel	4
Gravel	16
Tight gravel	11
Tight gravel	5
Cement clay	1

Well finished at 81 feet.

Pipe is cut from 80 feet to 50 feet.

Well No. 25—Line "H"

14-inch pipe 22 feet deep.

Sand	7
Soft gray clay	10
Hard gray clay	41
Yellow clay	7
Sand	3
Clean coarse gravel	15
Clay and gravel mixed	2
Coarse gravel	6
Gravel and rock	6
Coarse gravel	4
Light gray clay	7
Hard blue clay	19
Fine sand	9
Fine gravel	18
Yellow clay	1
Blue clay	2

Well finished at 157 feet.

Pipe not cut.

Well No. 7—Line "H"

14-inch pipe is 75 feet deep.

Material.	Depth, feet.
Soil	6
Clay	20
Blue sandy clay	6
Fine gravel	2
Yellow clay	31
Yellow clay	9
Fine gravel	13
Coarse gravel	13
Coarse gravel	7
Yellow clay	3

Well finished at 110 feet deep.
Pipe is not cut.

Well No. 20—Line "M"

14-inch pipe is 25 feet deep.

Material.	Depth, feet.
Soil	3
Yellow sandy clay	15
Gray clay	39
Gravel	10
Clean gravel	9
Clean gravel	6
Yellow sandy clay	9
Sand and fine gravel	12
Blue cemented gravel	5
Hard yellow clay	24

Well No. 4—Line "I"

14-inch pipe is 20 feet deep.

Material.	Depth, feet.
Soil	2
Yellow clay	13
Blue clay	5
Hard blue clay mixed	24
Hard blue clay mixed	1
Gravel	18
Tight gravel	11
Tight gravel	6
Yellow clay	1

Well is 81 feet deep.
Pipe cut from 50 to 86 feet.

Well No. 5—Line "M"

14-inch pipe 25 feet deep.

Material.	Depth, feet.
Black soil	2
Yellow sandy clay	18
Tough gray clay	19
Sand and gravel	11
Gravel	22
Hard yellow clay	11
Gravel	10
Yellow clay	4
Blue clay	20

Last run a light change to yellow clay.

Well No. 21—Line "L"

Material.	Depth, feet.
Sandy loam	15
Gray clay	9
Gray clay	13
Yellow clay	7
Fine gravel	2
Blue clay	16
Hard yellow clay	8
Gravel	8
Gravel	3
Gravel and clay mixed	3
Gravel	19
Yellow clay	4
Blue clay	8
Yellow clay	2
Coarse gravel	10
Yellow clay and gravel mixed	5
Gravel	9
Yellow clay	1
Hard yellow clay	8
Hard gray clay	38
Hard yellow clay	6
Cemented clay and gravel	2

Pipe not cut.

Well No. 15—Line "M"

14-inch pipe 26 feet deep.

Material.	Depth, feet.
Soil	6
Sand	9
Yellow clay	5
Blue clay	3
Blue clay	29
Gravel	2
Coarse gravel	30
Gray clay	5
Sand and fine gravel	21
Yellow clay	2
Fine cemented gravel	29

Well No. 10—Line "M"

14-inch pipe is 22 feet deep.

Material.	Depth, feet.
Black soil	4
Sand	7
Gray sandy clay	7
Gray clay	27
Coarse sand	5
Gravel	21
Blue clay	5
Sand and gravel	7
Gravel	6
Sand and gravel	9
Yellow clay	11

Material.	Depth, feet.
Fine gravel	15
Yellow cemented clay	3
Yellow sand	4
Yellow cemented gravel	19

Well No. 2

Material.	Depth, feet.
Sandy loam	16
Blue clay	13
Gravel	5
Blue clay	11
Soft clay and gravel	18

Well No. 5

(Similar to row west of hop yard.)

Material.	Depth, feet.
Sediment, top-soil	17
Stiff clay, dark	18
Mud and clay	15
Fine gravel	22
Coarse gravel	18

Well No. 7

(Under Flow Station No. 1.)

Material.	Depth, feet.
Surface soil	8
Blue clay	41
Med. gravel, tightly packed	4
Gravel	8

Well No. 9

Material.	Depth, feet.
Soil	14
Clay	46
Gravel	10

Log of old well 100.

Yards South of No. 9

Material.	Depth, feet.
Soil	16
Sand and clay	2
Blue clay	16
Gravel and sand	½
Blue and gray clay	28
Sand	2
Gravel	2

Well No. 11

Material.	Depth, feet.
Soil	8
Sand and gravel	12
Clay	30
Gravel	4

Well No. 13

(Under flow Station No. 3.)

Material.	Depth, feet.
Top soil (yellowish, sandy)	10
Clay	17
Blue clay	¾
Gravel	5¼

Well No. 14.

(Test well.)

Material.	Depth, feet.
Top soil (hardpan-gravel)	9
Sandy clay	28

Well No. 15

(Test well.)

Material.	Depth, feet.
Top soil	5
Coarse sand	8
Red sandy clay	49
Hardpan (gravel)	

Well No. 16

Material.	Depth, feet.
Adobe	2
Sandy loam	5
Sand and gravel	1
Brown clay	4
Yellow sand clay	13
Gravel	9
Yellow sand clay	2
Gravel and sand	9
Yellow sand clay	6
Gravel	11

Well No. 10

(Under flow Station No. 2.)

Material.	Depth, feet.
Sand loam	4
Heavy loam	3½
Sandy loam	4¾
Fine gravel	¾
Blue clay	46
Yellow sandy clay	3
Gravel	7

(At bottom of clay, coarse gravel is very tightly imbedded, forming almost hardpan. This changes to a med. gravel.)

Well No 17

(Test well.)

Material.	Depth, feet.
Top soil	6
Light, sandy clay	38
Hard bed clay and gravel	1
Hard, coarse gravel	

Well No. 18

Material.	Depth, feet.
Pit, surf. soil	27
Gravel	24
Yellow sand clay	9
Cement gravel	8
Yellow sand clay	1
Gravel	4
Yellow sand clay	5
Gravel	5

Material.	Depth, feet.
Yellow sand clay	5
Cement gravel	2
Yellow sand clay	4
Gravel	6
Yellow sand clay	2
Gravel	4
Yellow sand clay	1
Hard cement gravel	44½

Well No. 26

(Test well by S. V. W. Co.)

Surface soil	8
Gravel and sand	¾
Blue clay	41¼
Artesian gravel	6

Well No. 40

Soil	3
Sand	7
Clay	39
Gravel	14

Well No. 42

Soil	5
Sand (little water)	1..
Gray to blue, clay	8
Blue clay	7
Gray clay	13
Yellow sediment	10
Blue clay and sand	3
Blue clay and gravel	4
Coarse water gravel	17
Fine gravel and sand	13
Yellow clay	10
Blue clay, somewhat sandy	5
Clay (blue and gray)	2
Gray sandy clay, mostly sand	7
Blue clay	25

(Total depth = 130 feet.)

Well No. 46

(Test well.)

Blue clay	8
Sand and gravel	1
Blue clay	34
Yellow clay	3½
Gravel	

Well A

(At present S. V. W. Co.)

Soil	7
Quicksand	2
Gray clay	37

Material.	Depth, feet.

Well B

(At present S. V. W. Co.)

Soil	4
Blue clay	43

Well No. 34

Surface soil	18
Clay	½
Gravel and fine sand (loose quicksand)	

Well No. 36

Soil	1
Sand	9
Clay (yellow)	39
Gravel	3

Well No. 38

Surface soil	38
Gravel (Med.)	6

Well C

Soil	7
Quicksand	4
Blue clay	13
Gravel	17
Blue clay	24
Hardpan	2
Gravel	38
Blue clay	41
Gravel	10
Blue clay	24
Quicksand	5
Gravel	7
Blue clay	2
Gravel rock	12
Blue clay and rock	5
Gravel and rock	3

Well D

Soil	6
Sand	..
Quicksand	4
Blue clay	37
Gravel	25
Clay and sand	30

Well E

Soil	5
Quicksand	4
Clay	37
Gravel	4

Well F

Soil	1

Material.	Depth, feet.
Clay	18
Hardpan	14
Gravel	3

Well G

Soil	2
Clay and rocks	40
Gravel and hardpan	18
Blue clay	90
Gravel	3
Soapstone, blue	25

Well H

Soil	2
Clay	6
Quicksand	3
Clay sand	9
Hardpan	39
Blue clay	18
Quicksand	4
Hardpan	32
Blue clay	43
Sand rock	84
Blue clay and shale	35

Well No. 49

Well of Theo. Gier Wine Co. on place of Blaise Cortade.
(Sunk by Brenzle)

All gravel and no clay	60

Does not flow.

Well No. 48

Well of Theo. Gier Wine Co. on place of Blaise Cortade.
(Sunk by Brenzle)

Hard gravel and clay	60
Pure yellow clay	110
Quicksand	4

Then tapped a flow.
Artesian well flows year around.

Well No. 50

Well of Theo. Gier Wine Co. on main ranch.
(Sunk by Brenzle)

Clay	40
Gravel	20

Water at bottom of gravel.

Well No. 51

Well of Samuel Jackson

Material.	Depth, feet.
Gravelly soil	15-20
Clay	5
Gravel	35

Water rises to within 6 feet of top.

Well No. 52

M. Lopez well

Sandy soil	14
Clay	2
Gravel and quicksand	24
Depth	40

(Water within 12 feet of surface now, and never more than 19 feet from surface.)

Well No. 36

Remillard Brick Co's well

Pure gravel	46
Clay (hard yellow)	6

Plenty of water. Did not go through clay.
Well was in bottom of creek, hence no soil.
Gravel from smallest grain to size of fist—none larger.
Franciscan material.

Well No. 53

Mr. Scrivner's well

Soil	30
Gravel	35

Lots of water.

Well No. 54

Grant Gravel Co.'s well

Clean gravel	50
Hard yellow clay	7
Remainder clay and gravel	28
Depth	85

Dug in bottom of creek. First was blue gravel, second was brown gravel mixed with clay.

Well No. 55

Mr. Stoeven's well

Sandy loam	20
Clean gravel, no clay	50

Well No. 56

Mr. W. J. Holmes' well

Soil	4
Black loam with pebbles	12
Red clay	10
Clay, with pebbles which increase in size with depth	30

Material.	Depth, feet.
Remainder water-bearing gravel	56
Depth	112
Struck strong flow at bottom of well and lost all tools. Uses windmill.	

Well No. 57

Mr. Holmes, Sr. well (Sunk by Brenzle)

Clay	70
Clay and gravel	40

Well No. 58

Jacob Rees' well (Sunk by Brenzle)

Gravel and clay mixed	60

Well No. 59

Mr. James A. Bennet's well (Sunk by Brenzle)

Gravel and soil mixed	80

Well No. 60

Mr. J. Waggoner's well

Black gravelly soil	4
Coarse gravel with clay	56
Clear clay	12
Gravel	5
Depth	77

Well No. 60 (a)

Mrs. Freedenstall's well (Sunk by Draghi)

Loamy soil	2
Hard clay with very little gravel mixed	
Gravel and clay mixed, mostly gravel	20
Pure clay	30
Water-bearing fine sand	6
Pure water gravel	18
(No mud.) Did not go through gravel.	

Well No. 61

Mr. Ludwig's well (Sunk by Draghi)

Clay and gravel	50
Blue clay	50
Blue hard conglomerate	50
(Probably compact gravel.)	

Well No. 62

Mr. Sweeney's well (Sunk by Draghi)

Material.	Depth, feet.
Loose gravel	6
Clay and gravel	34
Pure yellow clay	15
Loose gravel	10
Hard conglomerate	95
Loose gravel	2
Hard conglomerate to	212

Well No. 63

Mr. Draghi's well (Sunk by Draghi)

Black soil and gravel	6
Yellow clay and gravel	46
Water gravel	4
Clay and gravel	20
Depth	76

Well No. 64

Mr. Huddleson's well (Sunk by Draghi)

Gravel and soil	15-20
Gravel and clay mixed	40
Hard yellow clay	2
Depth	57
(Water in gravel below)	

Well No. 65

Mr. C. A. Smith's well (Sunk by Draghi)

Loose gravel	20
Yellow clay	25
(Not very hard)	
Clay and gravel	10
Sand	1
Gravel and clay to	62
Remainder in hard clay	5-6

Well No. 66

Mr. Maguire's well (Sunk by Draghi)

Gravel and loam	12
Clay	18
Loose gravel with water	15
Clay	10
Clay and gravel about	10
Depth	55
(Very good well)	

Well No. 67

Mr. C. True's well (Sunk by Brenzle)

Hard yellow clay	110
Then gravel and water.	

Well No. 68

Captain J. Miller's well (Sunk by Brenzle)

Material.	Depth, feet.
Gravel and clay	72
Mixed to bottom.	

Well No. 69

Mr. H. Mangel's well
(Sunk by Brenzle)

Depth	47′ 6″
Water (from surface)	14
(Brenzle says all gravel and clay.)	60

Well No. 70

Mr. Maldonado's well
(Sunk by Brenzle)

Depth (all gravel)	40
Water from top	4

Well No. 71

Mr. Bissell's well
(Two wells about 60 yds. apart)
(Sunk by Brenzle)
Well No. 1 on upper bench near house

Gravel and soil	22
(Not water-bearing)	
Blue and yellow clays	22
(Mixed, each layer 4 to 5′ thick)	
Gravel—water-bearing	12
Water comes to 23′ of surface.	
Yellow clay with trace of small gravel mixed	15
Dry clay	129
Depth	200

(This well pumps 20,000 gals. every 24 hours. Water from 12′ water-bearing gravel.)

Well No. 72

Mr. Bissell's well
(Sunk by Brenzle)
Well No. 2 on lower bench, which is 19′ thick. Dug well.

Depth	16
Water nearly at surface. Never goes dry.	
All in gravel	16

Well No. 73

Livermore Water & Power Co.'s well
(Sunk by R. Wiley)
Well No. 1

Material.	Depth, feet.
Blue clay	7′
(Water 4′ from surface)	
Blue clay with old roots	2′
Blue clay is gritty	3′
Yellow clay with small gravel	1′ 5″
Coarse gravel and yellow clay	0′ 6″
Loose gravel	2′ 0″
Fine sand	2′ 0″
Yellow clay	2′ 0″
Fine sand mixed with clay	4′ 0″
Fine sand	0′ 6″
Coarse sand	0′ 6″
Fine sand	5′ 0″
Fine sand	4′ 0″
Yellow clay	12′ 0″
Reddish clay	2′ 0″
Yellow clay (very dry)	2′ 0″
Depth	50′ 3″

(Drilling was stopped here)

Well No. 74

Livermore Water & Power Co's well
Las Positas Springs Test Well No. 2
(300 to 500 ft. from well No. 1)

Adobe	7′ 0″
Blue clay—old roots	3′ 0″
Light blue clay—gritty	3′ 0″
Sandy	
Loose gravel—coarse	5′ 0″
Medium fine gravel and sand	4′ 0″
Yellow clay	2′ 0″
Yellow clay—gritty	8′ 0″
Yellow sand, rock, dust	2′ 0″
Sand rock dry	2′ 0″
Yellowish red clay	2′ 0″
Bluish yellow clay	4′ 0″
Clay and gravel	3′ 0″
Bluish clay and sand	2′ 5″
Stiff red clay	1′ 0″
Stiff red clay	1′ 5″
Depth	50′ 0″

Well No. 75

Joe Brown's well
(Sunk by Lefever)

Sandstone and water	340′
Hard sandstone	640′

(This is an artesian well.)

Well No. 76

Mr. Jas. Anderson's well
(Sunk by Brenzle)

Yellow and blue clay	20′
Sand and gravel	30′
Yellow clay with small gravel	25′
Hard yellow clay	8′

Material.	Depth, feet.
Yellow clay with small sand mixed	82′
Hard yellow clay	10′
Gravel with artesian water	6′
Blue clay with small gravel mixed	40′
Blue clay, hard	66′
Loose sand, good flow water	10′
Brown clay	10′
Blue clay	10′
Black sand (water-bearing 129,000 gals. per day)	
Hard blue clay	13′
Blue sand and clay	26′
Gray clay, hard	10′
Hard clay	16′
Loose sand and water	9′
Depth	398′
(Flows slowly from this depth.)	

Well No. 77

Livermore Pottery well
(Sunk by Draghi)

Clay and gravel	48′
Loose gravel	2′
Clay and gravel	50′

Well No. 78

Mr. James Whalen's well

Clay soil	12′
Gravelly loam	24′
Hard yellow clay	10′
Gravel	6′

Well No. 79

Schween Co.'s well

Gravelly soil	20′
Gravel and clay	15′
Pure clay	10′
Pure gravel	6′

Well No. 80

Mr. Freitas' well
(Sunk by Oxsen)

Loamy soil	30′
Yellow soft clay	15′
Hard yellow clay	3′
Water gravel	5′

Water is 15′ below surface.

Well No. 81

Ben Oxsen's well
(Sunk by Oxsen)

Gravel—no clay	58′

Water 6 to 7′ from surface.

Material.	Depth, feet.

Well No. 82

C. R. Nissen's well
(Sunk by Brenzle)

Loam (black)	5′ 6″
Clay	5′
Gravel	22′

Water 6′ from surface.

Well No. 83

F. H. Green's well

Depth	10′

Water 7′ to 8′ from surface.
No gravel.

Well No. 85

H. M. Jorgensen's well
(Sunk by Brenzle)

Gravel and soil mixed	28′
Sand, gravel and clay	71′

Water 28′ below surface.

Well No. 86

Albert Cojemann
(Sunk by Brenzle)

Red clay and gravel	140′

(Coarse gravel)
(Water 40′ below surface)

Well No. 87

Otto Ramkie's well
(Sunk by Brenzle)

Loam, gravelly soil	30′
Gravel	20′
Gravel—water-bearing	10′

Water stands 35′ below surface.

Well No. 88

Morx Ramkie's well
(Sunk by Brenzle)

Loam, gravelly soil	30′
Gravel	20′
Water, gravel	10′

Water stands 35′ below surface.

Well No. 89

John Galloway Sr. well
(Sunk by Brenzle)

Alternate strata of sand and clay	90′

Sand 1 to 5′ thick
Clay 5 to 10′ thick
Water 14′ from surface

Well No. 90

John Galloway Jr. well

Material.	Depth, feet.
(Sunk by Brenzle)	
Clay	45′
Gravel and clay mixed	63′
Water is 25′ below surface	

Well No. 91

Dan Enman's well
(Sunk by Brenzle)

Gravel and clay mixed	90′
Water 50′ below surface	
First water was struck at 50′	

Well No. 92

Holmes, Sr., well
(In field ¼ mile south of house)
(Sunk by Brenzle)

Clay	70′
Gravel, clay and boulders	50′
Water rose to 70′ of surface	

Well No. 93

Pete Kruger's well
(Sunk by Brenzle)

Loam	20′
Red clay and gravel	88′
Very little water	

Well No. 94

DeWitt Dougherty's well
(Sunk by Brenzle)

Red gravel and clay mixed	70′
No water	

Well No. 95

Mr. Cassidy's well

Material.	Depth, feet.
(Sunk by Brenzle)	
Gravel	10′
Clay and gravel	30′
Loam, gravel and sand	70′

This is up in the soft Miocene country.

Well No. 96

H. P. Mohr's well
(Sunk by Oxsen)

Loamy soil	30′
Gravel	10′

This well was never artesian.

A well belonging to Mohr about ¾ mile north of this well was artesian in 1909 and 1911.

LOGS OF SUNOL WELLS.

Between Scott's Corner and Water Temple.

Well No. 1

Gravel	37′
Sand and clay	14′
Gravel	29′
Clay and gravel	18′
Shale	23′

Well No. 2

Soil	9′
Gravel	31′
Sand	23′
Gravel	62′
Clay	11′
Gravel	26′
Shale	48′

Appendix F.

REPORT ON COYOTE RIVER SYSTEM

BY

H. MONETT,

Assistant Engineer, Spring Valley Water Company.

The upper Coyote River and its tributaries has a watershed whose topography is very similar to that of Calaveras Creek. The upper reaches of the Coyote River watershed, to the south of Mt. Hamilton and ranging in elevation from 3600 feet in the extreme northern part to about 500 feet in the south, is in the north as effective a water-producer as the Calaveras territory. In the extreme south this productiveness is probably diminished materially, but over a range of country stretching from the Spring Valley Water Company's proposed damsite "D," as shown on the map, Plate (F-A-1), to the ridge separating this watershed from that of Calaveras the rainfall is comparatively high and the percentage of available run-off is above the average for this region of California.

Rainfall.

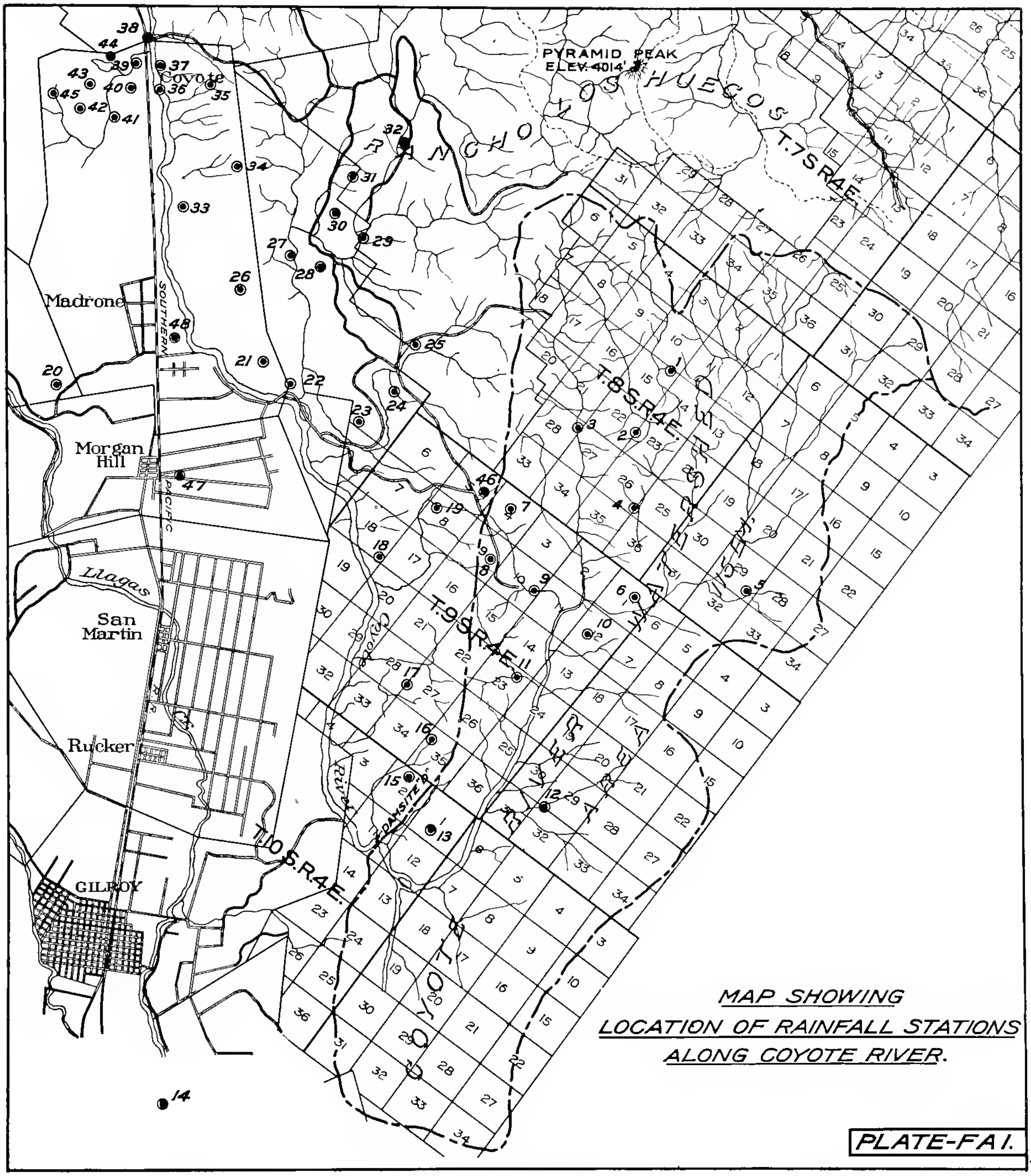
From the rainfall data collected by Messrs. Haehl and Toll and published in Vol. 61 of the Transactions of the American Society of Civil Engineers (pages 531-532), a portion of the rainfall data shown on Plate (F-A-1, F-A-2) was obtained. There are records of thirteen stations covering from two to seven seasons within the 115 square miles of watershed, the drainage area above the proposed damsite designated as damsite "D" by the Spring Valley Water Company. These 13 station records have been expanded over 63 years by means of percentage comparisons with the means of two secondary base stations, San Jose and Gilroy, these two stations being previously expanded, as secondary base stations, to cover a 63-year period by comparison with San Francisco, the longest rainfall record available in these parts.

This percentage comparison was made as follows: The actual records of San Jose and Gilroy cover a period of 38 years, from 1874-75 to 1911-12. Computing the ratios of the means of these two stations to the mean of San Francisco, the primary base station for the same period, we have two factors to use in multiplying the remainder of the San Francisco record from 1849-50 to 1874-75, which gives us a continuous estimated and actual rainfall record for the two secondary base stations (San Jose and Gilroy) for the 63 years, 1849-50 to 1911-12. A mean of these two records gives a composite base upon which the 48 records shown on Plate (F-A-2) were, by a method similar to that described above, expanded for the same 63-year period.

The method above described is in conformity with the best engineering practice of treating rainfall records, having been frequently used by engineers experienced in studies of rainfall and run-off in this vicinity, and probably gives the most reliable results where long period rainfall records are not available.

An inspection of Plate (F-A-1) shows the thoroughness with which this rainfall survey was made, all possible areas where local conditions might vary the seasonal precipitation being covered.

The 13 stations inside the 115 square miles of watershed under consideration vary from a minimum of 17.36 inches to a maximum of 33.37 inches in the neighborhood of Mt. Hamilton. The stations being well scattered over the watershed, it is a fair assumption to use the mean of these 13 gagings as the mean rainfall over the area considered. This mean is 26.56 inches.



THE COYOTE CATCHMENT AREA LIES JUST SOUTH OF MT. HAMILTON. MANY RAINFALL RECORDS HAVE BEEN TAKEN IN THIS VICINITY.

◉ Indicates rainfall record.

Rainfall Records on Coyote River
as given in Vol. 61. Trans. Am. Soc. C.E. with deduced 63 season mean.

					63 Season.							63 Season.	
No.	Time of Record	Gaged Record	Mean of Base Sta.	Percent.	Base Sta. Mean	Deduced Mean	No.	Time of Record	Gaged Record	Mean of Base Sta.	Percent.	Base Sta. Mean	Deduced Mean
1	Jan.'03-Aug.'05	80.46	46.31	173.70	18.68	32.45	26	Sep.'03-Aug.'05	34.45	34.94	96.60	18.68	18.42
2	" "	82.69	"	178.60	"	33.37	27	" "	38.36	34.94	109.80	"	20.51
3	" "	43.02	"	92.90	"	17.36	28	Jan.'03- "	50.44	46.31	108.90	"	20.33
4	" "	55.50	"	119.80	"	22.38	29	" "	52.16	46.31	112.60	"	21.02
5	" "	61.51	"	132.80	"	24.81	30	Sep.'03- "	37.01	34.94	105.90	"	19.78
6	" "	54.40	"	117.50	"	22.13	31	" "	37.67	34.94	107.80	"	20.15
7	" "	67.93	"	146.70	"	27.40	32	Jan.'03- "	57.63	46.31	124.40	"	23.23
8	" "	63.60	"	137.30	"	25.66	33	Sep.'03-Aug.'07	81.47	82.98	98.18	"	18.33
9	Sep.'03-Aug.'06	97.26	57.18	170.10	"	31.78	34	" Aug.'05	34.44	34.94	98.58	"	18.40
10	" -Aug.'05	47.59	34.94	136.20	"	25.45	35	" "	32.79	34.94	93.85	"	17.53
11	Jan.'03- "	67.69	46.31	146.20	"	27.31	36	" Aug.'07	76.56	82.98	92.26	"	17.23
12	" "	68.82	46.31	148.60	"	27.75	37	Jan.'03-Aug.'05	44.94	46.31	97.05	"	18.13
13	" "	66.82	46.31	144.30	"	26.96	38	Sep.'03- "	33.74	34.94	96.58	"	18.03
14	Sep.'99-Aug.'06	113.48	125.21	90.60	"	16.92	39	" Mar.'08	98.37	95.13	103.40	"	19.30
15	Sep.'03-Aug.'05	59.58	34.94	170.50	"	31.85	40	Sep.'99-Aug.'04	117.32	82.50	142.20	"	26.56
16	Jan.'03- "	69.71	46.31	150.50	"	28.11	41	Sep.'03-Aug.'06	53.37	57.18	93.34	"	17.43
17	Sep.'03- "	50.01	34.94	143.10	"	26.72	42	Sep.'04-Aug.'05	18.01	18.50	97.36	"	18.16
18	" "	46.78	34.94	133.90	"	25.00	43	Sep.'03-Aug.'07	80.61	82.98	97.14	"	18.13
19	Jan.'03- "	68.26	46.31	147.40	"	27.53	44	" "	77.50	82.98	93.40	"	17.45
20	Sep.'03- "	39.43	34.94	112.80	"	21.08	45	Sep.'04-Aug.'05	19.64	18.50	106.20	"	19.82
21	" "	30.04	34.94	85.98	"	16.23	46	Jan.'03- "	61.23	46.31	132.20	"	24.70
22	" Mar.'08	118.35	95.13	124.40	"	23.21	47	Sep.'99-Aug.'04	135.67	82.50	164.50	"	30.73
23	Jan.'03-Aug.'06	89.26	68.55	130.20	"	24.30	48	Jan.'03-Mar.'08	130.51	106.50	122.50	"	22.86
24	" Aug.'05	57.85	46.31	124.90	"	23.32		Total.	——			——	1099.32
25	" "	59.57	46.31	128.60	"	24.01		Mean.	——			——	22.90

PLATE-FA2.

ALL AVAILABLE RAINFALL RECORDS IN THE NEIGHBORHOOD OF THE COYOTE RIVER SYSTEM WERE EXPANDED TO 63 YEARS, BY COMPARISON WITH OTHER LONGER RECORDS.

The Gilroy station, being in the immediate vicinity, is the best available index of the rainfall over this watershed for periods not covered by the records within the watershed, and its actual mean of 19.95 inches was multiplied by the factor 1.331 (the ratio of 26.56 to 19.95) in order to give the proper value to each successive year in the mean rainfall over the entire area. Having a complete table (shown below) of the probable mean rainfall over this area from 1849-50 to 1911-12 as given here, the run-off conditions are as follows:

TABLE SHOWING EXPANDED GILROY RAINFALL, SAN FRANCISCO USED AS A BASE STATION.

Season—	Gilroy Rainfall.	Gilroy Rainfall x 133.10%
1849-50	28.62	38.07
1850-51	6.42	8.55
1851-52	15.96	21.24
1852-53	30.48	40.57
1853-54	20.64	27.47
1854-55	20.54	27.34
1855-56	18.72	24.92
1856-57	17.21	22.91
1857-58	18.86	25.10
1858-59	19.23	25.60
1859-60	19.26	25.64
1860-61	17.03	22.67
1861-62	42.60	56.70
1862-63	11.88	15.81
1863-64	8.72	11.61
1864-65	21.39	28.36
1865-66	21.07	28.04
1866-67	30.20	40.20
1867-68	33.58	44.70
1868-69	18.50	24.62
1869-70	17.37	23.12
1870-71	12.20	16.24
1871-72	26.22	34.90
1872-73	14.26	18.98
1873-74	20.62	27.45
1874-75	15.12	20.12
1875-76	31.04	41.31
1876-77	6.53	8.68
1877-78	28.03	37.31
1878-79	16.76	22.31
1879-80	22.38	29.79
1880-81	23.42	31.17
1881-82	14.09	18.75
1882-83	15.19	20.22
1883-84	24.60	32.74
1884-85	14.74	19.62
1885-86	21.45	28.55
1886-87	11.11	14.77
1887-88	16.78	22.33
1888-89	14.44	19.22
1889-90	37.75	50.21
1890-91	14.84	19.75
1891-92	18.91	25.17
1892-93	24.50	32.61
1893-94	12.91	17.18
1894-95	28.81	38.35
1895-96	24.70	32.88
1896-97	21.82	29.04
1897-98	10.44	13.90
1898-99	19.44	25.87
1899-00	14.54	19.35
1900-01	23.17	30.84
1901-02	18.41	24.50
1902-03	17.48	23.27
1903-04	18.26	24.30
1904-05	23.25	30.94
1905-06	29.42	39.16
1906-07	28.98	38.57
1907-08	14.25	18.97
1908-09	27.81	37.02
1909-10	19.47	25.91
1910-11	19.38	25.80
1911-12	13.87	18.46
Total	1269.67	1689.75
Mean	20.16	26.80

Run-off.

The accurate gagings made in conjunction with the precipitation records, above discussed, and covering seven complete seasons are shown in the following table:

GAGINGS OF COYOTE RIVER.
Tributary Catchment Area 193.20 sq. mi.

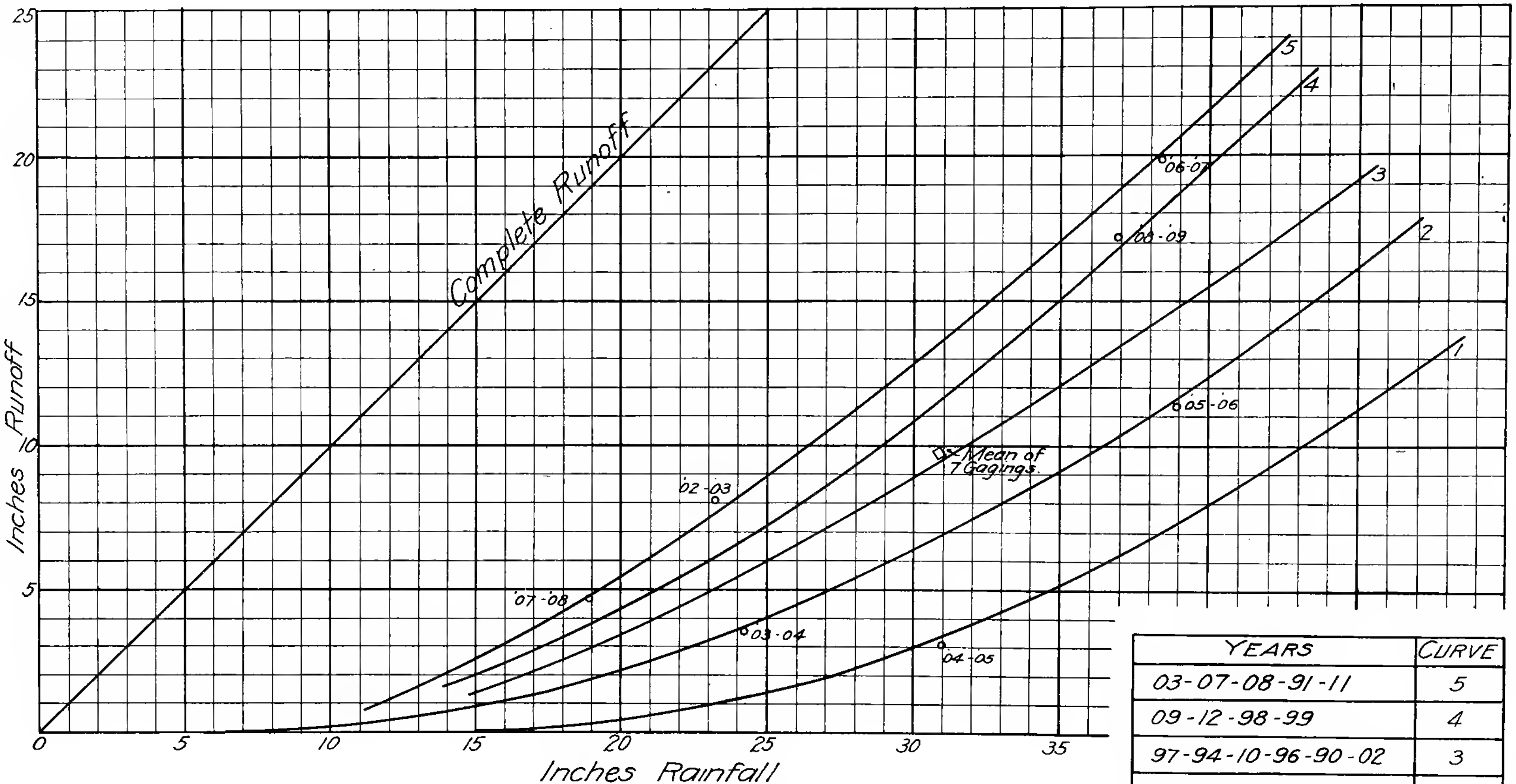
Season	Run-off M. G.	Run-off inches	Rainfall 133.10% of Gilroy
1902-03	27,070	8.066	23.27
1903-04	11,611	3.460	24.30
1904-05	10,396	3.098	30.94
1905-06	37,928	11.300	39.16
1906-07	66,517	19.820	38.57
1907-08	15,442	4.602	18.97
1908-09	57,637	17.170	37.02
Total	226,601	67.516	212.23
Mean	32,731	9.645	30.71
M. G. D.	88.69	0".02643	

1" over watershed = 3356 M. G.

These gagings were taken at a point several miles below the damsite of the proposed Coyote Reservoir, designated as damsite "D."

From studies of the measured run-off of Alameda Creek (see Appendix B), it was determined that within the 23 years, 1889-90 to 1911-12, there existed a cycle of eight dry years. It was also found that the run-off varied for different seasons having practically the same seasonal precipitation, and that reliable results could best be obtained by arranging the 23 seasons into five groups, each of which fulfilled different conditions of run-off.

There is every reason to believe that this same grouping applies to all the catchment areas in this vicinity and the same method has, therefore, been used in computing the run-off for the



YEARS	CURVE
03-07-08-91-11	5
09-12-98-99	4
97-94-10-96-90-02	3
00-04-93-92	2
95-05-01	1

CURVES showing relation between Rainfall and Runoff on Coyote River Watershed of 115 Sq. Mi for 23 year period from 1889-90 to 1911-12

Plate-F2

BY GROUPING THE YEARS ACCORDING TO PERCENTAGE OF RUN-OFF, VERY RELIABLE RESULTS MAY BE OBTAINED.

Coyote River above the reservoir for the 23 years, 1889-90 to 1911-12. Therefore, the measured run-offs, expressed in inches, and their corresponding precipitations were plotted co-ordinately, resulting in five curves (Plate F-2.), indicating as nearly as possible the run-off with consideration for the important factors, namely: intensity, amount, and distribution of rainfall. From the table of gagings the season 1902-03 has a rainfall of 23.27 inches and a run-off of 8.07 inches, while the season 1903-04 has a rainfall of 24.30 inches and a run-off of 3.46 inches, from which it is seen that with a difference of only 1.03 inches in rainfall there is a difference in run-off of 4.61 inches. This is due, of course, to the factors mentioned.

The data being at hand to enable a complete study to be made of the rainfall and run-off of the Alameda Creek System for the 23-year period from 1889-90 to 1911-12, which shows similar climatic variations to that of the Coyote drainage area, such data was used as a basis for determining the flow of Coyote River for the same period, as is particularly shown in the following table. From this calculation a progressive summation or mass curve was projected, as shown on Plate F-3.

Capacity of Reservoir.

A survey of the reservoir site made by the engineers of the Spring Valley Water Company in 1903 (Plate F-4), gives a capacity of 9065 M. G. with a dam 150 feet high.

A detailed analysis of this mass diagram showed that the determining period or the criterion for deducing the dependable draft for the given storage occurred in the years from 1899-1900 to 1902-03. Reference to the mass diagram shows that a gross draft of 23.01 M. G. D. would just empty the reservoir in the season of 1901-02. From this gross draft, allowance must be made for loss due to evaporation.

By means of a contour map the estimated area of the water surface five feet below the top of the dam was determined to be 517 acres.

On page 382 of the "Engineering News" of February 29, 1912, Mr. Edwin Duryea, Jr., gives the results of some experiments on the evaporation of water from water surfaces. These experiments were made at the Upper Gorge, about 11 miles from the proposed reservoir. His results are given in Appendix "D," and indicate that the seasonal evaporation from a water surface in this locality amounts to 45 inches. Assuming the evaporation to amount to 48 inches a year, in order to make a conservative estimate, the quantity over this water surface is 1.85 M. G. D., or a net draft of 23.01—1.85 = 21.16, M. G. D.

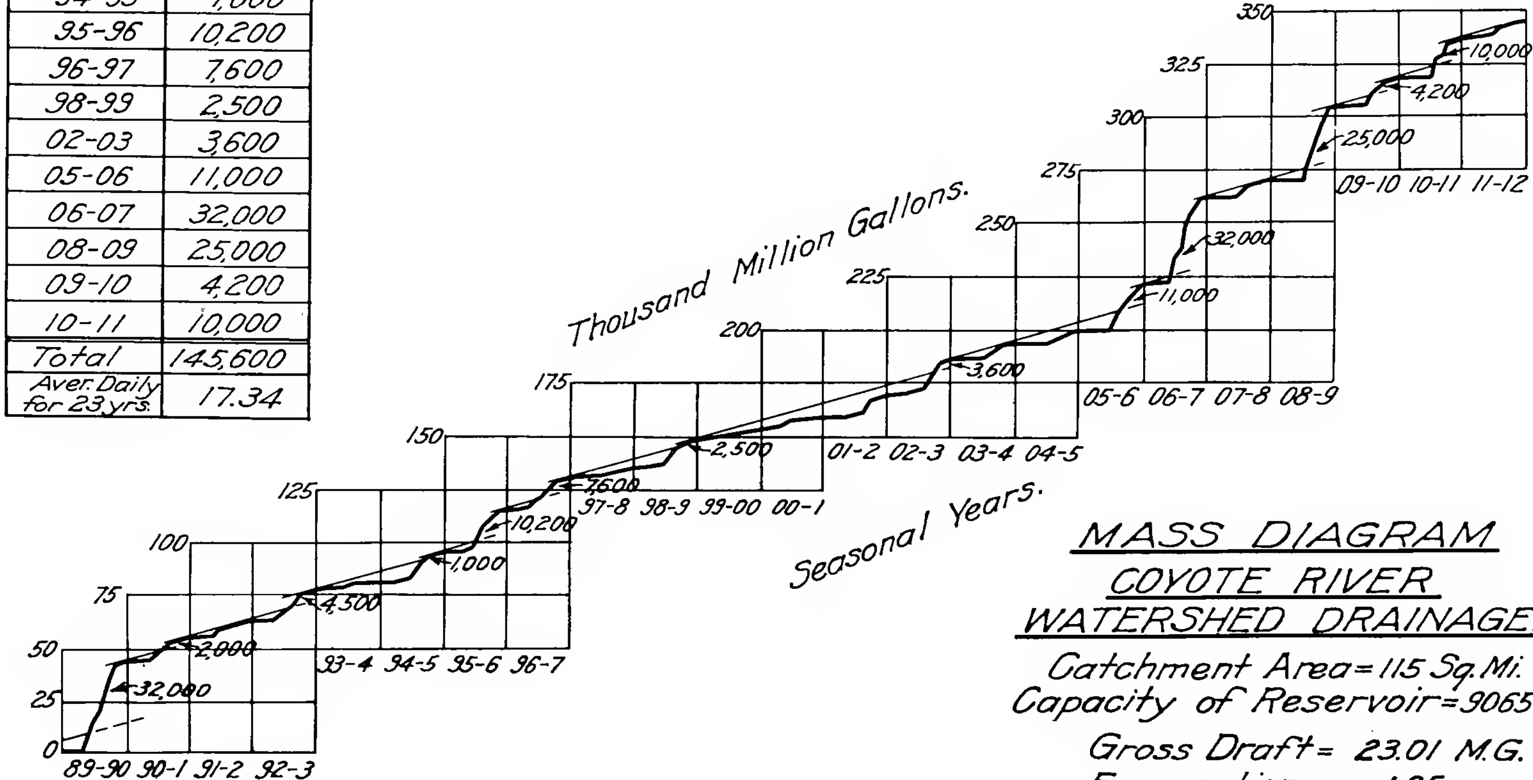
TABLE SHOWING RELATION BETWEEN RAINFALL AND RUN-OFF FOR 23 YEARS.

Season	Mean rainfall over 115 sq. mi.	Run-off in inches	Run-off in mill. gall. Area 115 sq. mi.	Run-off in mill. gall. Area 193.2 sq. mi.	Difference
1889-90	50.21	22.75	45,430	76,360	30,930
1890-91	19.75	5.00	9,985	16,780	6,795
1891-92	25.17	4.00	7,988	13,423	5,435
1892-93	32.61	7.50	14,980	25,170	10,190
1893-94	17.18	1.25	2,496	4,196	1,700
1894-95	38.35	7.00	13,980	23,490	9,510
1895-96	32.88	10.50	20,970	35,240	14,270
1896-97	29.04	8.00	15,980	26,850	10,870
1897-98	13.90	1.50	2,996	5,034	2,038
1898-99	25.87	8.10	14,980	25,170	10,190
1899-00	19.35	1.80	3,595	6,041	2,446
1900-01	30.84	3.20	6,390	10,740	4,350
1901-02	24.50	5.50	10,980	18,460	7,480
1902-03	23.27	#8.07	16,120	27,070	10,950
1903-04	24.30	#3.46	6,910	11,611	4,701
1904-05	30.94	#3.10	6,191	10,396	4,205
1905-06	39.16	#11.30	22,570	37,928	15,358
1906-07	38.57	#19.82	39,580	66,517	26,937
1907-08	18.97	#4.60	9,186	15,442	6,256
1908-09	37.02	#17.17	34,290	57,637	23,347
1909-10	25.91	6.30	12,580	21,140	8,560
1910-11	25.80	9.50	18,970	31,880	12,910
1911-12	18.46	4.30	8,587	14,430	5,843
Total	642.05	173.72	345,734	581,005	235,271
Mean	27.91	7.554	15,030	25,260	10,230
M. G. D.	.....	.....	41.18	69.21	28.03

#Actual gagings.

WASTE PERIODS

Years	M. G.
89-90	32,000
90-91	2,000
92-93	4,500
94-95	1,000
95-96	10,200
96-97	7,600
98-99	2,500
02-03	3,600
05-06	11,000
06-07	32,000
08-09	25,000
09-10	4,200
10-11	10,000
Total	145,600
Aver. Daily for 23 yrs.	17.34



MASS DIAGRAM
COYOTE RIVER WATERSHED DRAINAGE.

Catchment Area = 115 Sq. Mi.
Capacity of Reservoir = 9065 M.G.

Gross Draft = 23.01 M.G.
Evaporation = 1.85 " "
Net Draft = 21.16 M.G

Plate-F-3.

OVER 21 M. G. D. FROM THE COYOTE RIVER SYSTEM IS AVAILABLE FOR THE METROPOLITAN DISTRICT.

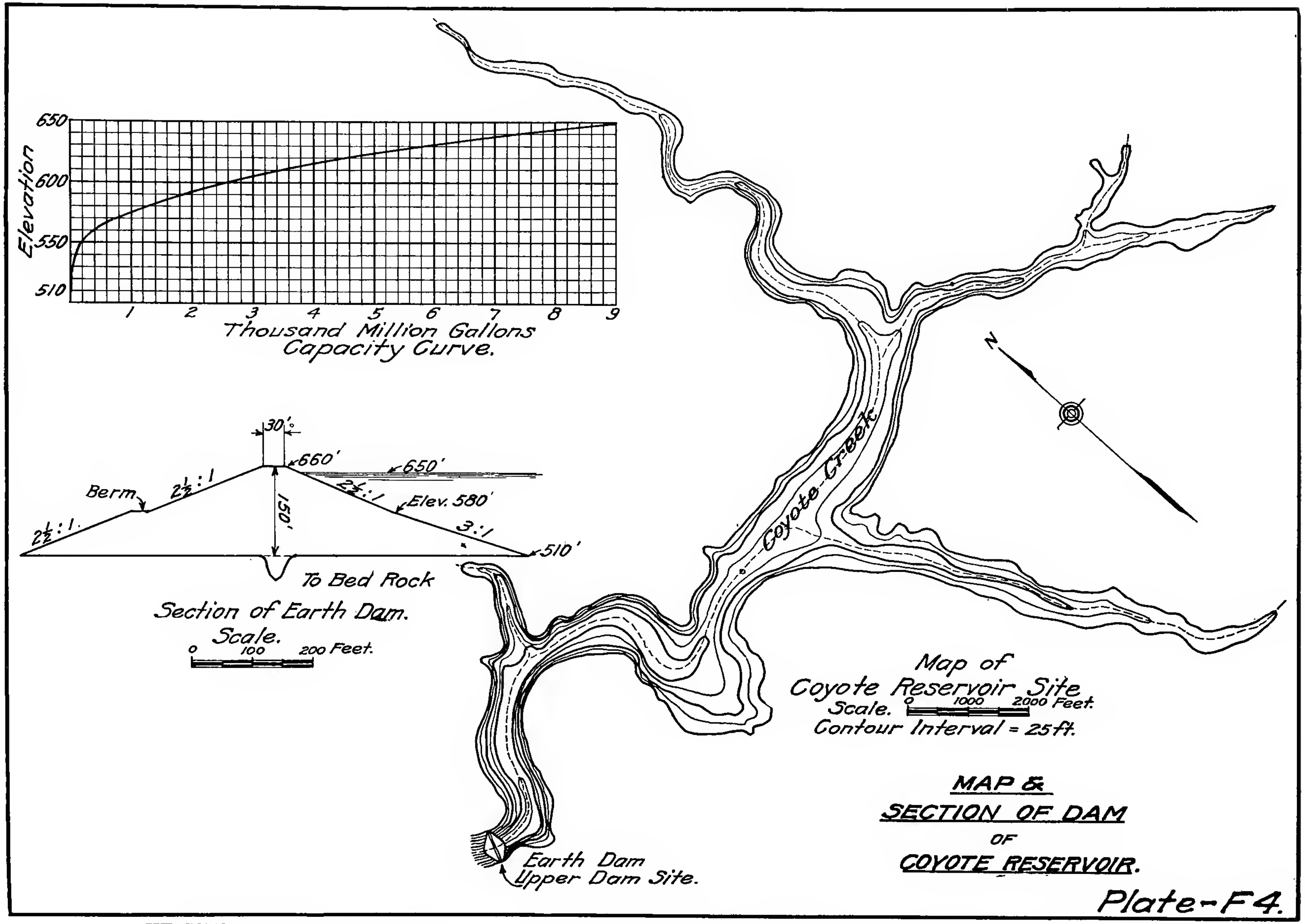
The reservoir would be full in the years shown in the following table as waste years:

TABLE SHOWING WASTE YEARS.

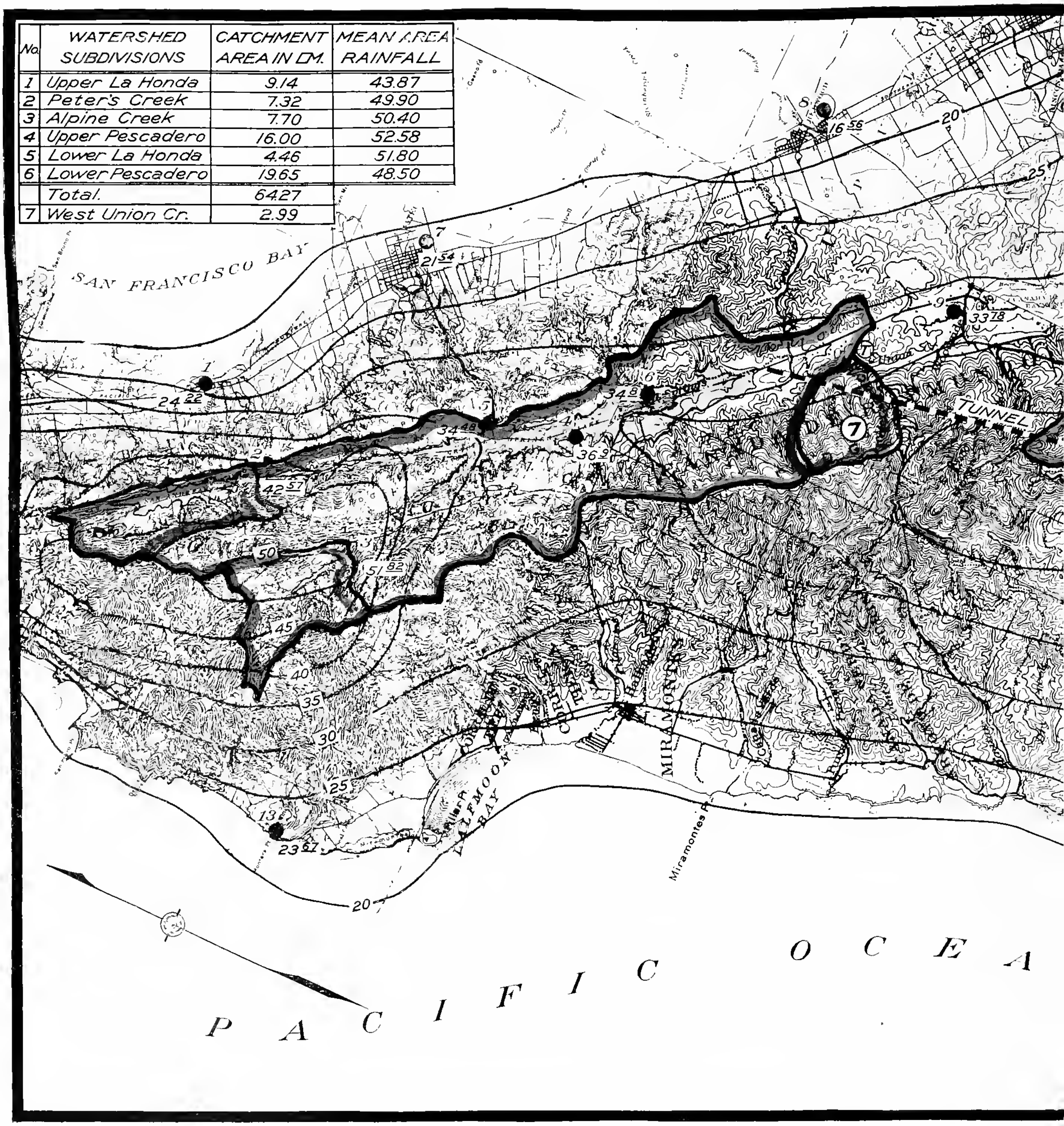
Season	M. G.
1889-90	32,000
1890-91	2,000
1891-92	0
1892-93	4,500
1893-94	0
1894-95	1,000
1895-96	10,200
1896-97	7,600
1897-98	0
1898-99	2,500
1899-00	0
1900-01	0
1901-02	0
1902-03	3,600
1903-04	0
1904-05	0
1905-06	11,000
1906-07	32,000
1907-08	0
1908-09	25,000
1909-10	4,200
1910-11	10,000
1911-12	0
Total	145,600
M. G. D.	17.34

A table has been constructed giving the total amount of run-off measured at the place where the seven years' gagings were taken (above which there is a catchment area of 193.2 square miles), together with the difference between this amount and that derived from the 115 square miles above the Coyote Reservoir. This difference gives an average of about 28 M. G. D., which is carried on down into Santa Clara Valley. The table on Plate F-3 shows the frequency and amounts of the waste over the 23-year period. The sum of these wastes makes an average total of 45 M. G. D. going into the valley below.

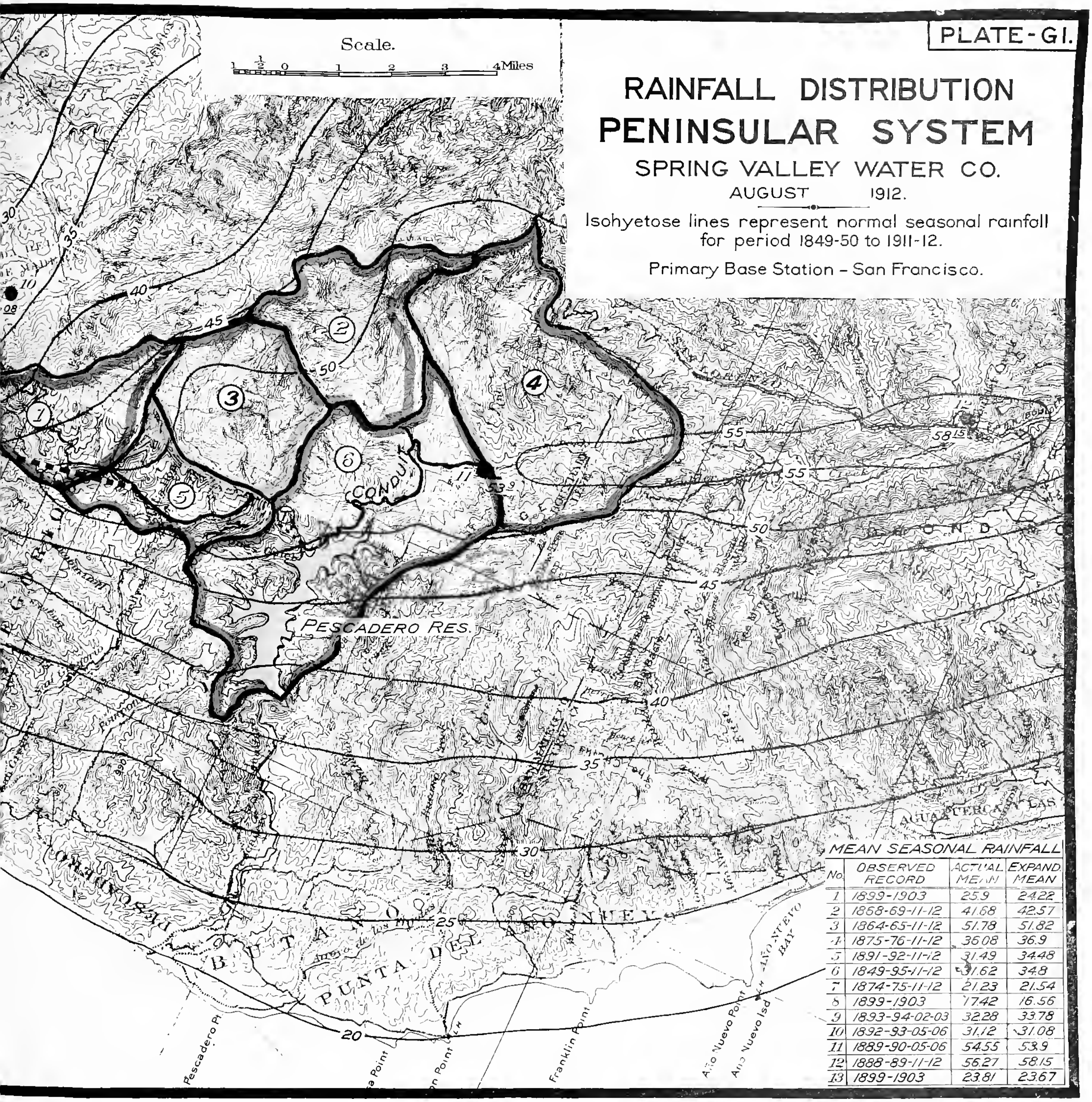
An analysis of the table of gagings shows a mean discharge for the seven years of 88.69 M. G. D., with a rainfall of 30.71 inches, or a mean seasonal run-off of 9.645 inches. The mean in inches for the 23 years is 7.554 inches with a rainfall of 27.91 inches.



THE COYOTE RESERVOIR WILL CONSERVE THE FLOODS FOR THE USE OF THE METROPOLITAN DISTRICT.



No.	WATERSHED SUBDIVISIONS	CATCHMENT AREA IN DM.	MEAN AREA RAINFALL
1	Upper La Honda	9.14	43.87
2	Peter's Creek	7.32	49.90
3	Alpine Creek	7.70	50.40
4	Upper Pescadero	16.00	52.58
5	Lower La Honda	4.46	51.80
6	Lower Pescadero	19.65	48.50
	Total.	64.27	
7	West Union Cr.	2.99	



MEAN SEASONAL RAINFALL			
No.	OBSERVED RECORD	ACTUAL MEAN	EXPAND. MEAN
1	1899-1903	25.9	24.22
2	1868-69-11-12	41.68	42.57
3	1864-65-11-12	51.78	51.82
4	1875-76-11-12	36.08	36.9
5	1891-92-11-12	31.49	34.48
6	1849-95-11-12	31.62	34.8
7	1874-75-11-12	21.23	21.54
8	1899-1903	17.42	16.56
9	1893-94-02-03	32.28	33.78
10	1892-93-05-06	31.12	31.08
11	1889-90-05-06	54.55	53.9
12	1888-89-11-12	56.27	58.15
13	1899-1903	23.81	23.67

Appendix G.

REPORT ON COAST STREAMS AND WEST UNION CREEK

BY

I. E. FLAA.

Assistant Engineer Spring Valley Water Company.

The catchment area of the coast streams is on the western or ocean slope of the peninsula mountains. It is covered with a virgin forest of firs and redwoods. The mean seasonal rainfall at Pilarcitos (elevation 695′), whose watershed joins that of the coast streams on the north and east, is 51.78 inches as determined by 37 years of actual records. The actual mean seasonal rainfall of the Boulder Creek catchment area is 56.27 inches and is determined by 22 years' gagings at Boulder Creek (elevation 470′), whose watershed joins that of the coast streams on the south.

The mean seasonal rainfall on Pescadero Creek at Camp Howard is 54.55 inches, as determined by 17 years of actual gaging. This rainfall is high, due to frequent fogs, and the temperature, even in summer, is cool. These several factors combine to regulate the run-off and produce a marked increase in the summer flow.

In this report only San Gregorio and Pescadero Creeks are used in the proposed development.

Pescadero and San Gregorio Creeks.

It is proposed to divert the run-off of Pescadero and San Gregorio Creeks, by gravitation and pumping, into Crystal Springs Reservoir through a system of concrete-lined conduits and tunnels. (See Plate G-1.) All that portion of the catchment area above 422 feet elevation is available for the gravity system, or about 40.16 square miles out of the 64.27 square miles above Pescadero Reservoir site. All run-off in these upper catchment areas in excess of the conduit capacity is impounded in the Pescadero Reservoir to be pumped back into the conduit system.

The catchment area tributary to the conduit is 40.16 square miles (see Plate G-1), divided as follows:

Upper La Honda	9.14	sq. mi.
Peters Creek	7.32	"
Alpine Creek	7.70	"
Upper Pescadero	16.00	"
Total	40.16	"

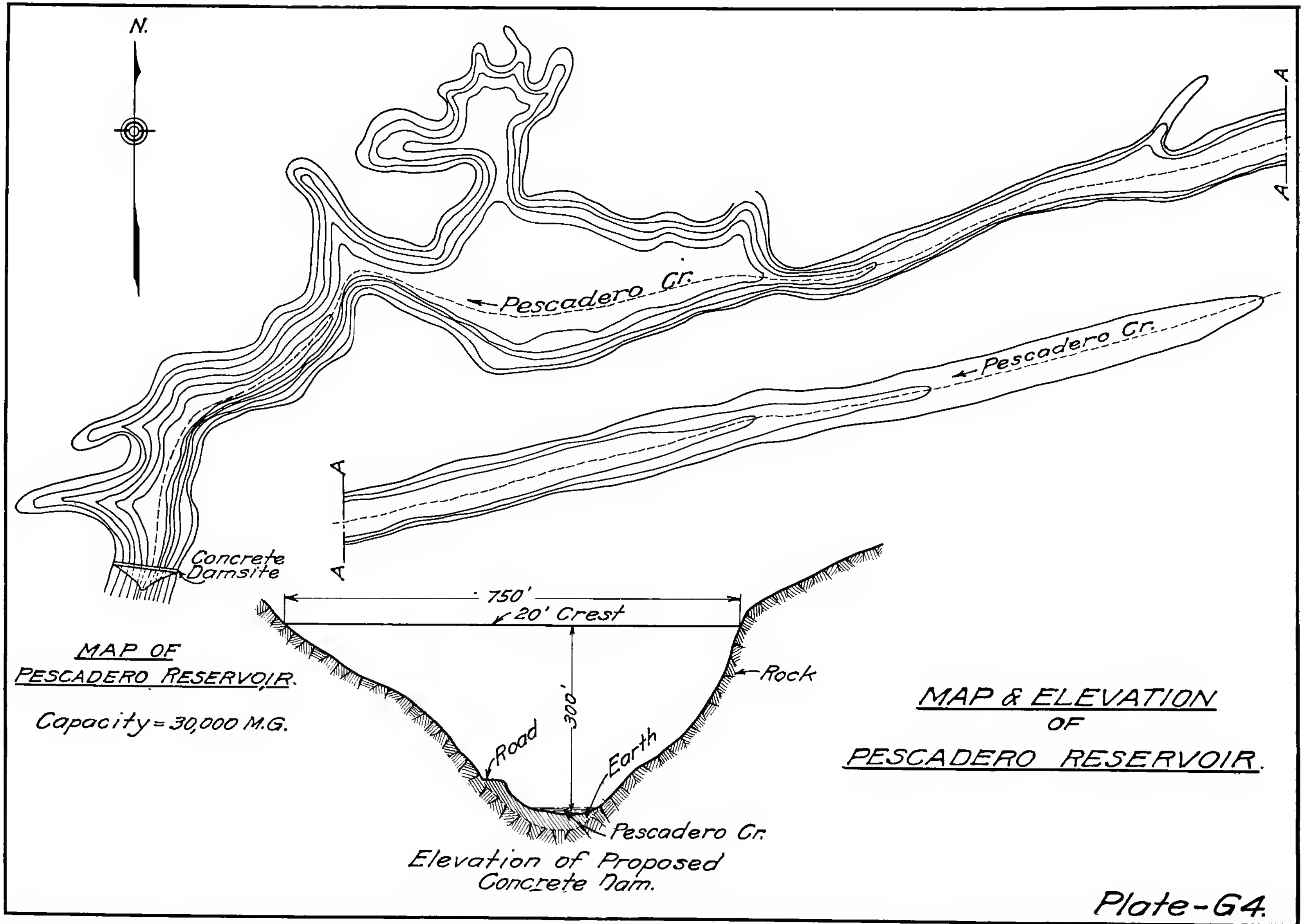
The catchment area of Pescadero Reservoir, excluding 40.16 square miles tributary to conduit, is 24.11 square miles, the total area of Coast streams being 64.27 square miles. The Pescadero Reservoir has a storage capacity of 30,000 M. G., with a 310-foot dam. (See Plate G-4.)

Rainfall.

Nineteen rainfall stations on the Peninsula having records for a period ranging from 5 to 63 years, were expanded into a 63-year period by comparison with the 63-year record of San Francisco and other long period records. The mean annual rainfall for 63 years for each station was then determined. (See table.)

The mean annual records so determined were then located upon a map and curves of equal rainfall or isohyetose lines were drawn. (See Plate G-1.)

From this map, by use of the planimeter, the mean area rainfall over each subsidiary catchment area, as well as the entire catchment area, was determined in the manner described in the preceding Appendix "A".



LYING WITHIN A DENSELY FORESTED WATERSHED OF UNUSUALLY HIGH RAINFALL AND PROVIDING 30,000 MILLION GALLONS STORAGE.

MEAN SEASONAL RAINFALL.

Station	Observed Record	No. of Years	Actual Mean	Expanded Mean	Elevation
San Francisco	1849-50—1911-12	63	22.80		
Boulder Creek	1888-89—1911-12	24	56.27	58.15	470
Crystal Springs Cottage	1894-95—1911-12	18	31.62	34.80	300
Crystal Springs—Lower	1891-92—1911-12	22	31.49	34.48	300
Crystal Springs—Upper	1875-76—1911-12	37	36.08	36.90	300
Los Gatos	1885-86—1911-12	27	33.89	34.69	600
Menlo Park	1878-79—1911-12	34	16.99	17.10	64
Pescadero	1889-90—1905-06	17	54.55	53.90	
Pilarcitos	1864-65—1911-12	48	51.78	51.82	695
Portola	1892-93—1905-06	14	31.12	31.08	370
San Andreas	1868-69—1911-12	44	41.68	42.57	445
San Jose	1874-75—1911-12	38	15.28	15.32	95
San Mateo	1874-75—1911-12	38	21.23	21.54	22
Santa Cruz	1878-79—1911-12	34	27.66	28.31	20
Woodside	1893-94—1902-03	10	32.28	33.78	600
Pt. Montara	1899-1903	5	23.81	23.67	
Redwood City	1899-1903	5	17.42	16.56	
So. San Francisco	1899-1903	5	19.95	20.48	
Millbrae	1899-1903	5	25.90	24.22	

The results of these calculations are shown in table below:

Catchment Area	Area in Square Miles	Mean Area Rainfall for 63-Year Period in Inches
Upper La Honda	9.14	43.87
Peters Creek	7.32	49.90
Alpine Creek	7.70	50.40
Upper Pescadero	16.00	52.58
Lower La Honda	4.46	51.80
Lower Pescadero	19.65	48.50
Total	64.27	Mean..49.50

Run-off.

Daily rainfall records for 17 years, 1889-90 to 1905-06, and stream gagings for a period of 7 years were taken on Pescadero Creek at Camp Howard (catchment area 16 square miles) by the Spring Valley Water Company, from which the seasonal run-off per square mile of catchment area of Pescadero Creek for 6 years, 1899-1900 to 1905-06, was determined as follows:

PESCADERO RUN-OFF.

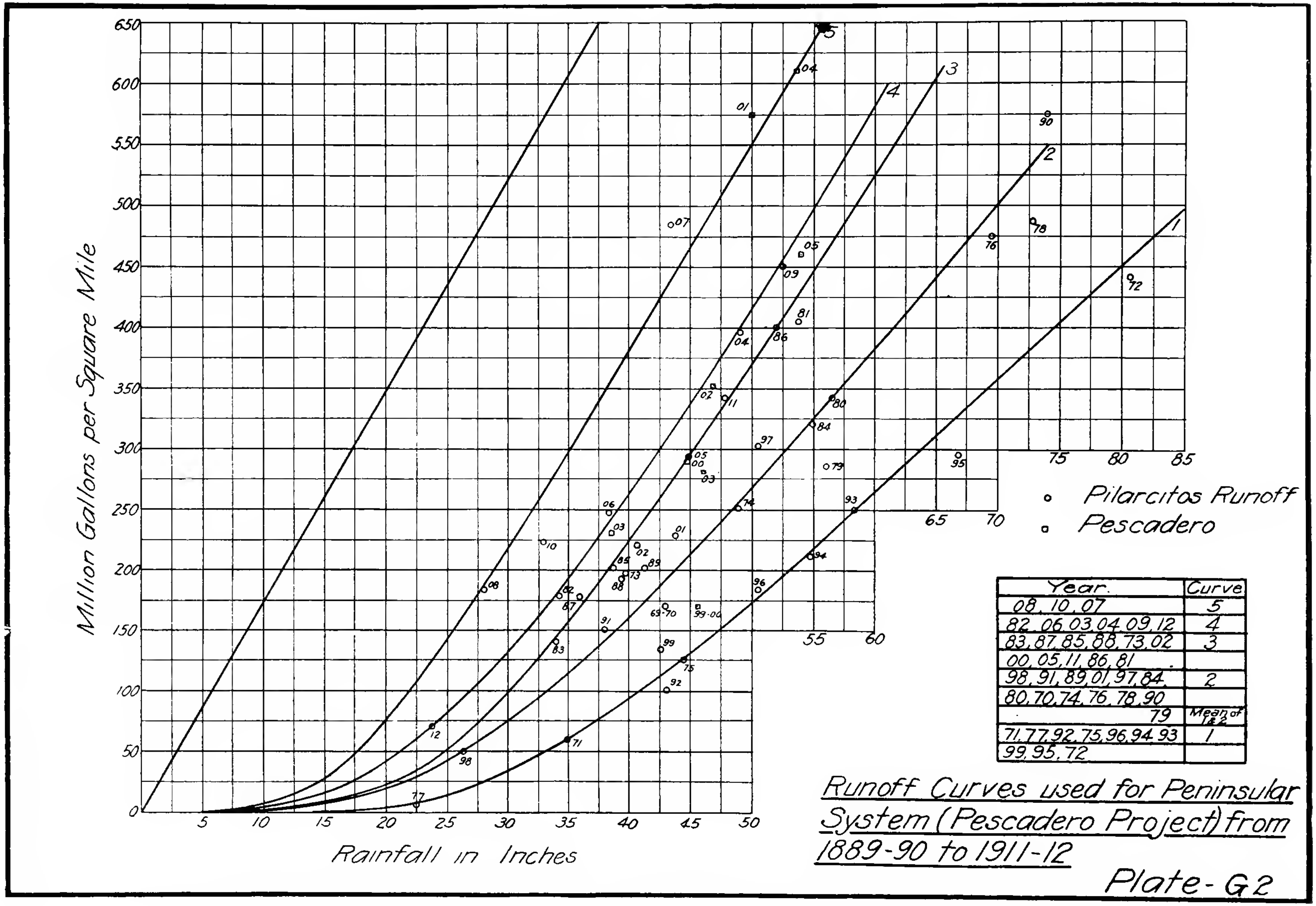
Season	Areal Rainfall In.	Pescadero Actual Run-off M. G.	Run-off per Square Mile M. G.
1899-1900	45.5	2655.13	165.95
1900-1901	49.9	9178.98	573.62
1901-1902	46.6	5658.85	353.68
1902-1903	45.9	4507.50	281.70
1903-1904	53.6	9742.80	608.99
1904-1905	54.0	7395.20	462.20

Pilarcitos and San Andreas Reservoir catchment areas are of a similar nature to that of Pescadero with respect to location, elevation, topography, size of catchment area and climate. Actual rainfall and run-off records for a period of 43 years, from 1869-70 to date have been taken and are tabulated below.

RAINFALL AND RUN-OFF PILARCITOS AND SAN ANDREAS.

Season	Run-off M. G. per Sq. Mi.	Rainfall Inches
1869-70	168.4	43.13
1870-71	62.4	35.09
1871-72	444.0	80.58
1872-73	197.4	39.17
1873-74	253.5	48.97
1874-75	125.0	44.37
1875-76	475.0	69.48
1876-77	6.1	22.37
1877-78	487.0	72.85
1878-79	288.0	56.10
1879-80	344.0	56.55
1880-81	405.0	53.89
1881-82	178.0	34.27
1882-83	138.0	33.91
1883-84	320.0	54.99
1884-85	203.0	38.21
1885-86	399.0	51.94
1886-87	177.0	35.66
1887-88	194.0	38.75
1888-89	204.0	41.17
1889-90	576.0	73.67
1890-91	152.0	37.78
1891-92	103.0	43.13
1892-93	250.0	58.30
1893-94	211.0	54.86
1894-95	296.0	66.93
1895-96	184.0	50.44
1896-97	304.0	50.47
1897-98	47.0	26.26
1898-99	134.0	42.56
1899-00	290.0	44.71
1900-01	232.0	43.87
1901-02	238.0	40.68
1902-03	328.0	38.00
1903-04	397.0	48.70
1904-05	294.0	44.79
1905-06	246.0	37.82
1906-07	485.0	43.47
1907-08	184.0	28.07
1908-09	452.0	52.37
1909-10	223.0	32.90
1910-11	347.0	47.78
1911-12	72.0	23.70

These records were used in conjunction with the 7-year records of Pescadero (see table, page



THE RELATION BETWEEN RAINFALL AND RUN-OFF ON COAST STREAM FOR 43 YEARS.

437) in the construction of five curves showing the run-off in M. G. per square mile per inch of rainfall. (See Plate G-2.) Five curves are used, each one showing different conditions of intensity and distribution of yearly precipitation. They depart quite materially from the average curve of run-off to precipitation. Further discussion of the development and construction of these curves is unnecessary, as they are similar to those used in the discussion of the Alameda Creek System (Appendix B), and also to those used in the discussion on Coyote Creek rainfall and run-off (Appendix F).

The actual run-off of 16 square miles of Pescadero Creek was expanded by area rainfall relation, to cover the remaining 40.16 square miles by comparing this rainfall (50 inches) to that of Pescadero (53.4 inches), or 92%. Applying this percentage to the expanded rainfall at Pescadero, we obtain the annual area rainfall for the 40.16 square miles over a period of 23 years, as shown in column 1 of the table.

Applying these mean area rainfalls to the proper run-off curve we obtain the run-off as shown in column II of same table, with the exception of the six seasons, 1899-1900 to 1904-05, where the actual run-off at Pescadero was used.

For calculating the overflow quantities during the storm periods the daily run-off from the upper Pescadero catchment area was used as a base. As the problem to be solved involves both a gravity flow conduit and a reservoir of known capacity, the contents of which are to be pumped into a conduit that leads to Crystal Springs Reservoir, it was necessary to assume certain capacities for the various gravity flow conduits. The assumptions are made as follows:

Upper Pescadero	28	M. G. D.
Peters Creek	13	"
North La Honda	16	"
Alpine Creek	13	"
Total gravity flow	70	"

The sections of this conduit increase in carrying capacity as follows:

Upper Pescadero	28	M. G. D.
Between Peters and N. La Honda	41	"
Between North La Honda and Alpine	57	"
Between Alpine and Tunnel	70	"

The run-off and the conduit capacity of the Upper Pescadero area being known, the overflow quantities were calculated from the daily readings.

As the same rate of run-off was assumed for all other areas, the run-off was calculated as follows:

Peters	45%	of Upper Pescadero
North La Honda	57%	"
Alpine	48%	"

The capacity of the various feeders also being known, the overflow quantities were calculated by the same methods used for the Upper Pescadero. The total overflow quantities were found for the area of 40.16 square miles to be as follows:

1899-1900	3,640	M. G.
1900-1901	7,580	"
1901-1902	9,175	"
1902-1903	4,690	"
1903-1904	17,800	"
1904-1905	7,420	"

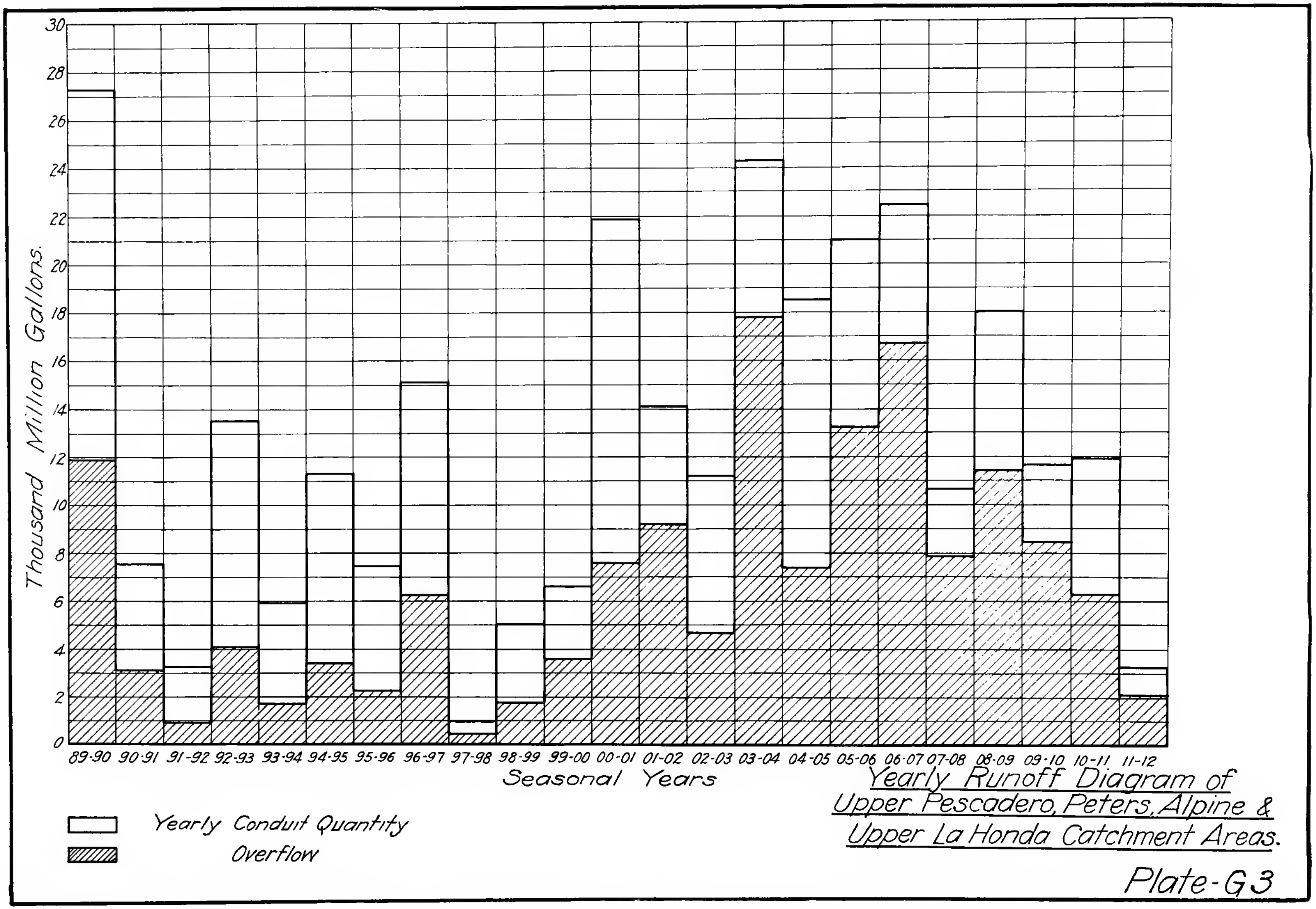
The actual run-off quantities from the Upper Pescadero are as follows:

1899-1900	2,655	M. G.
1900-1901	9,178	"
1901-1902	5,658	"
1902-1903	4,507	"
1903-1904	9,742	"
1904-1905	7,395	"

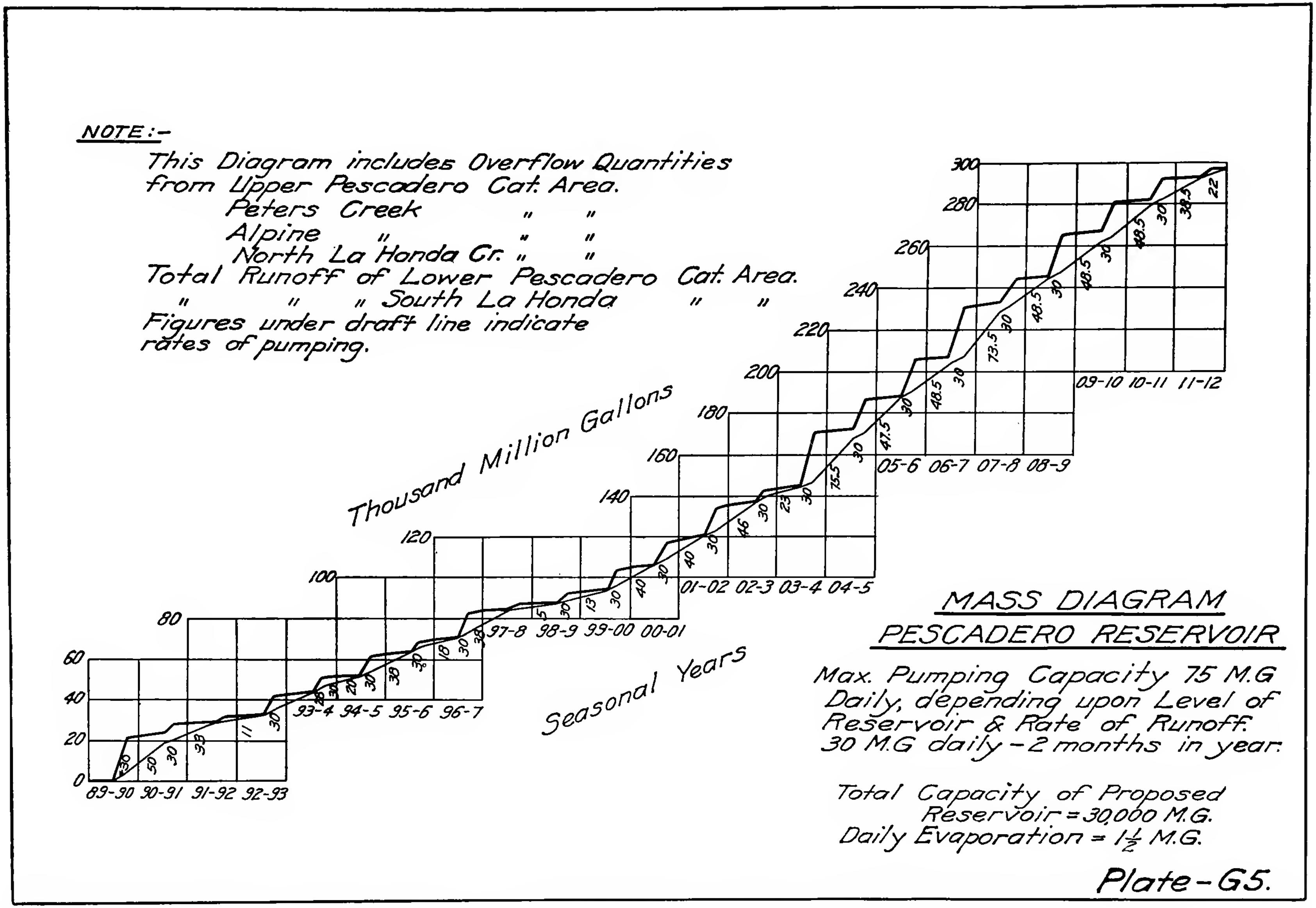
As the total catchment area that involves the gravity flow conduit is 40.16 square miles, the total run-off was taken as approximately 2.5 times the actual run-off of the Upper Pescadero catchment area. The actual quantities of run-off, conduit flow and overflow are as follows:

Season	Run-off	Overflow	Conduit Flow
1899-1900	6,625	3,640	2,985
1900-1901	21,950	7,580	14,370
1901-1902	14,150	9,175	4,975
1902-1903	11,250	4,690	6,560
1903-1904	24,350	17,800	6,550
1904-1905	18,490	7,420	11,070

For expanding over a period of 23 years a rate of run-off per square mile was used depending upon the seasonal rate of rainfall, applied to its respective curve as shown on Plate G-2. This value multiplied by the total area of



HYDROGRAPH SHOWING THE QUANTITY OF WATER FLOWING DIRECTLY INTO THE CRYSTAL SPRINGS RESERVOIR AND THAT WHICH REACHES THE PESCADERO RESERVOIR.



WATER FROM PESCADERO RESERVOIR WOULD BE TRANSFERRED TO CRYSTAL SPRINGS RESERVOIR AT RATES SHOWN IN THIS DIAGRAM.

40.16 square miles gave the expanded values of run-off, found in table.

From a series of five percentage curves found by plotting the known run-off quantities of the Pilarcitos, San Andreas and the six known quantities of the Pescadero areas the overflow values were found which are given in the above mentioned table. The difference between run-off and overflow quantities gave the amount of water running in conduits for seasonal years, as shown by columns III and IV of table, and diagramatically on Hydrograph Plate G-3.

The Lower Pescadero or Reservoir Catchment Area.

The reservoir being supplied by the overflow quantities of the above mentioned catchment areas and the run-off of the area itself, together with the Lower La Honda drainage (see Plate G-1), it is necessary to calculate run-off from the areas mentioned. There being an intervening ridge between the catchment area of the Lower La Honda and the reservoir, all the water will have to be passed through a tunnel. The same methods of calculations were used as mentioned in first part of description years, as shown in column 1 of the table.

TABLE OF RUN-OFF FROM UPPER PESCADERO, PETERS, ALPINE AND UPPER LA HONDA CATCHMENT AREAS.

Season	Rainfall I	Total Run-off II	Overflow III	Yearly Conduit Flow IV
1889-90.....	86.0	26,130	11,190	14,940
1890-91.....	42.1	7,236	3,100	4,136
1891-92.....	37.4	3,136	983	2,153
1892-93.....	66.8	12,945	4.060	8,885
1893-94.....	45.8	5,628	1,760	3,868
1894-95.....	62.8	10,895	3.417	7,478
1995-96.....	50.3	7,156	2,242	4,914
1896-97.....	58.0	14,471	6,200	8,271
1897-98.....	22.3	1,045	447	598
1898-99.....	39.1	5,000	1,822	3,178
1899-00.....	43.8	6,625	3,640	2,985
1900-01.....	48.0	21,950	7,580	14,370
1901-02.....	44.8	14,150	9,175	4,975
1902-03.....	44.2	11,250	4,690	6,560
1903-04.....	51.6	24,350	17,800	6,550
1904-05.....	52.0	18,490	7,420	11,070
1905-06.....	55.4	20,100	13,200	6,900
1906-07.....	47.6	21,227	16,560	4,667
1907-08.....	32.4	10,211	7,800	2,411
1908-09.....	51.2	17,288	11,380	5,908
1909-10.....	37.2	11,658	8,500	3,158
1910-11.....	48.6	14,000	6,180	7,820
1911-12.....	24.0	2,934	2,058	876
M. G. D..		34.29	18.0	16.28

TABLE OF RUN-OFF OF LOWER PESCADERO AND LOWER LA HONDA CATCHMENT AREAS AND OVERFLOW QUANTITIES FROM OTHER CATCHMENT AREAS.

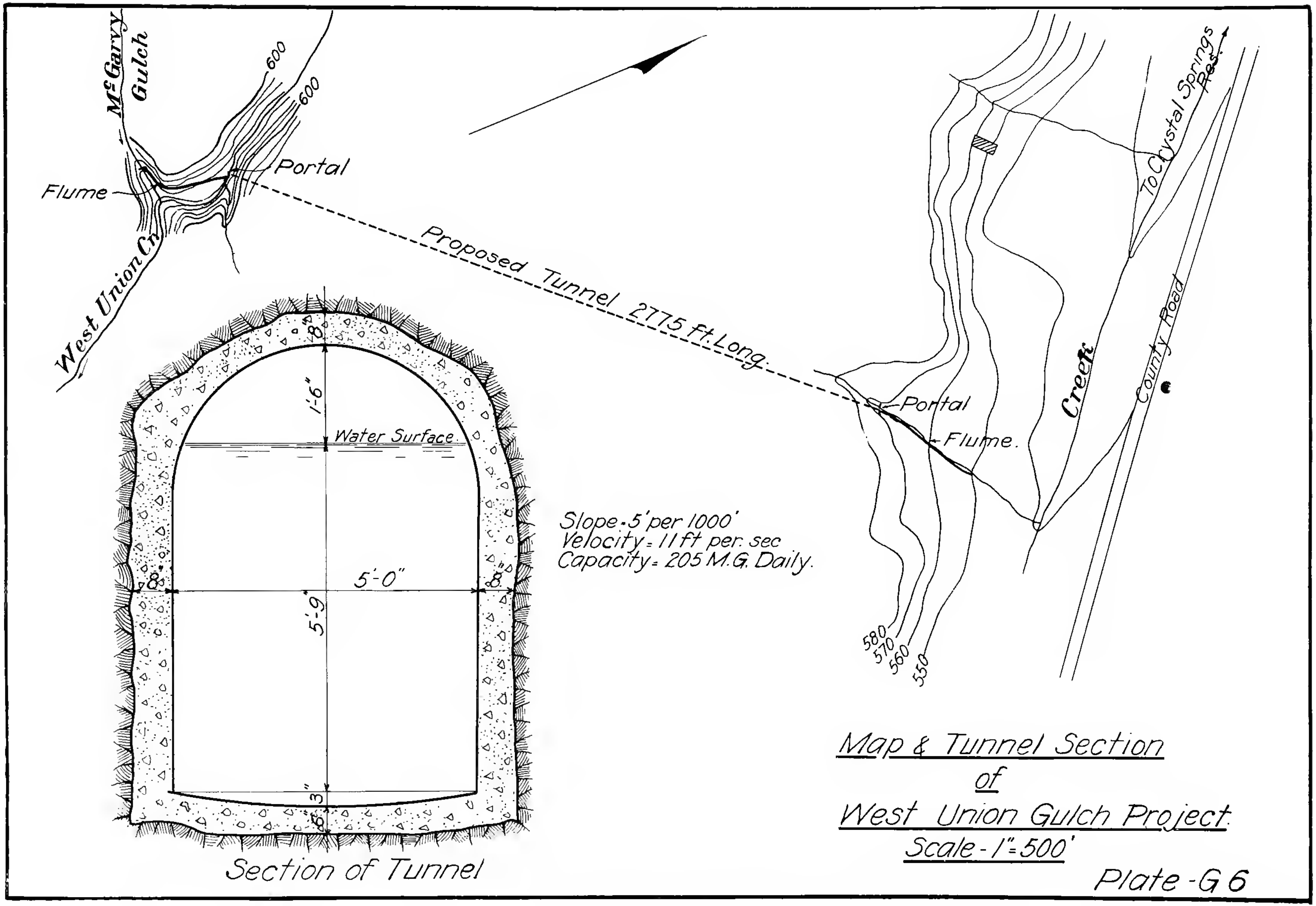
Season	Lower Pescadero I	Overflow II	Lower La Honda III	Total IV
1889-90.....	9,460	11,190	2,163	22,813
1890-91.....	2,620	3,100	632	6,352
1891-92.....	1,920	983	824	3,727
1892-93.....	5,370	4,060	1,356	10,786
1893-94.....	5,380	1,760	1,389	8,529
1894-95.....	6,340	3,417	1,730	11,487
1895-96.....	3,770	2,242	948	6,960
1896-97.....	6,660	6,200	1,676	14,536
1897-98.....	1,220	447	324	1,991
1898-99.....	3,095	1,822	829	5,746
1899-00.....	6,810	3,640	1,722	12,172
1900-01.....	5,400	7,580	1,331	14,311
1901-02.....	5,720	9,175	1,593	16,488
1902-03.....	2,460	4,690	1,048	8,198
1903-04.....	8,740	17,800	2,204	28,744
1904-05.....	5,544	7,420	1,414	14,378
1905-06.....	4,855	13,200	1,248	19,303
1906-07.....	8,260	16,560	2,055	26,875
1907-08.....	3,520	7,800	907	12,227
1908-09.....	7,670	11,380	1,914	20,964
1909-10.....	4,150	8,500	1,073	13,723
1910-11.....	5,570	6,180	1,439	13,189
1911-12.....	1,387	2,058	358	3,803
M. G. D...	13.81	18.00	3.59	35.41

The results in last column of the table were plotted in mass curve (Plate G-5), from which the draft or pumping from Pescadero Reservoir was determined.

The reservoir being used only for the storage of storm flow and being some 200 feet below conduit level, it is necessary to raise the water to this level. The rate of pumping being arbitrary, depending upon the level and capacity of reservoir, it was found that the best conditions would be to pump a maximum daily capacity of 30 M. G. for the months of January and February. For the other remaining months a maximum pumping capacity of 75 M. G. could be used, depending, as mentioned above, on the reservoir level. From mass curve (Plate G-5) it is seen that 75 M. G. would only have been used for two periods of 10 months each in the past 23 years and that a quantity of 50 M. G. would be a more constant one.

Conclusions as to Productivity of Coast Streams.

The Coast streams are capable of producing a gross run-off of 51.69 M. G. D. Deducting 1.5 M. G. D. for evaporation, in Pescadero Reservoir, we have a net draft of 50.19 M. G. D.



PLAN AND DETAIL OF DIVERTING TUNNEL FROM WEST UNION CREEK TO THE CRYSTAL SPRINGS RESERVOIR.

Of this 50.19 M. G. D. about 16.28 M. G. D. will flow by gravity, while 33.91 M. G. D. will be pumped into Crystal Springs Reservoir via the gravity conduit and tunnel.

West Union Creek.

The West Union Creek catchment area is on the eastern or Bay slope of the peninsular mountains, adjoining that of Upper Crystal Springs Reservoir on the south. With respect to location, topography, climate and vegetation it is practically the same as that of Crystal Springs Reservoir.

In this project it is proposed to divert the run-off from 1.95 square miles of West Union Creek and 1.04 square miles of McGarvey Gulch, a tributary to West Union Creek, into Crystal Springs Reservoir, by about 500 feet of concrete-lined conduit and 2775 feet of concrete-lined tunnel. (See details on Plate G-6 and location on Plate G-1.)

No rainfall or run-off records for West Union Creek being available, the run-off per square mile from the Crystal Spring Reservoir catchment area was applied to the 2.99 square miles of West Union Creek for a period of 23 years, 1889-1890 to date, the results being as shown on following table. From these results it is seen that West Union Creek produces an average of 1.54 M. G. D.

TABLE OF RUN-OFF OF WEST UNION CREEK CATCHMENT AREA (2.99 SQ. MI.)

Season.	M. G.
1889-90	334
1890-91	562
1891-92	236
1892-93	1,056
1893-94	725
1894-95	1,230
1895-96	472
1896-97	558
1897-98	...
1898-99	312
1899-00	354
1900-01	241
1901-02	206
1902-03	457
1903-04	825
1904-05	441
1905-06	602
1906-07	1,021
1907-08	336
1908-09	1,160
1909-10	377
1910-11	1,266
1911-12	117
M. G. D.	1.54

Appendix H.

HYDROGRAPHIC DATA

Compiled by

George G. Anderson, C. E.

The data given in the following tables were compiled and used by Mr. Anderson in the determination of the productivity of the Spring Valley Water Company's ultimate development in his report on "The Possible Yield From the Alameda, the Peninsula and the Lake Merced Systems."

RAINFALL AT APTOS—ELEVATION 102.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1885	....	....	....	....	....	....	2.86	0.19	0.43	1.78	0.13	0	.....	1885	20.14
1885-86	0.18	0	0.07	0.02	10.65	3.83	7.61	0.80	4.09	7.10	0.27	0	34.62	1886	22.94
1886-87	0	0	0	0.70	0.84	1.53	0.95	8.82	0.76	1.61	0.19	0	15.40	1887	17.68
1887-88	0	0	0.47	0.05	1.11	3.72	5.85	1.59	5.32	9.50	0.79	0.25	28.65	1888	33.81
1888-89	0	0	0.45	0	5.75	4.31	0.50	0.87	5.90	0.85	1.71	0	20.34	1889	37.94
1889-90	0	0	0	7.49	2.33	18.29	10.29	4.60	3.16	1.25	1.66	0	49.07	1890	33.97
1890-91	0	0	0.40	9.40	0.28	2.93	1.08	13.16	3.01	2.84	0.20	0	33.30	1891	29.27
1891-92	0	0	1.00	0.07	0.27	7.64	0.92	4.90	2.67	1.95	2.47	0	21.89	1892	27.30
1892-93	0	0	0.65	1.36	3.66	8.72	3.40	3.41	7.97	1.54	0.42	0	31.13	1893	23.93
1893-94	0	0	0.22	0.33	3.16	3.48	7.56	6.05	0.92	0.89	2.50	0.24	25.35	1894	37.12
1894-95	0	0	2.00	2.93	0.71	13.32	11.80	2.95	2.85	1.88	1.39	0	39.83	1895	24.86
1895-96	0	0.76	0	0.15	1.53	2.31	9.63	0	2.90	5.01	1.59	0	23.88	1896	32.20
1896-97	0	0	0.26	1.64	5.92	4.49	1.28	6.27	4.03	0	0.30	0.10	24.29	1897	15.88
1897-98	0	0	0	1.69	0.82	1.39	1.23	3.52	1.17	0.32	1.17	0.20	11.51	1898	12.36
1898-99	0	0	1.40	0.76	0.75	1.84	6.43	0.22	13.14	1.25	1.00	0	26.79	1899	36.65
1899-00	0	0	0	6.01	4.24	4.36	4.56	0.53	2.19	1.53	0.59	0	24.01	1900	22.02
1900-01	0	0	0.27	1.58	8.95	1.82	4.95	5.25	1.10	2.25	0.25	0.10	26.52	1901	19.52
1901-02	0	0	0.48	1.52	2.60	1.02	2.12	10.99	3.19	1.82	0.56	0.10	24.40	1902	26.69
1902-03	0	0	0	2.95	2.86	2.10	5.42	2.62	7.32	1.62	0	0	24.89	1903	24.10
1903-04	0	0	0.30	0.54	5.99	0.29	1.71	5.90	9.68	2.33	0.38	0.05	27.17	1904	30.03
1904-05	0	0.21	3.56	2.83	1.65	1.73	5.17	5.28	4.22	1.87	2.89	0.05	29.46	1905	24.50
1905-06	0	0	0	0	3.01	2.01	6.96	6.10	7.57	1.52	4.04	0.35	31.56	1906	40.36
1906-07	0	0	0.50	0	2.04	11.28	10.28	3.87	12.56	0.42	0.11	0.98	42.04	1907	37.37
1907-08	0	0	0.46	1.80	0	6.89	4 99	3.95	0.88	0.74	0.46	0	20.17	1908	18.23
1908-09	0	0	0.15	1.40	2.37	3.29	20.33	8.97	4.26	0	0	0.17	40.94	1909	46.72
1909-10	0	0	0.85	1.32	1.82	9.00	5.06	1.93	4.38	0.66	0	0	25.02	1910	15.99
1910-11	0	0	0.15	1.23	0.73	1.85	15.75	4.69	8.10	2.08	0.20	0.30	35.08	1911	36.01
1911-12	0	0	0	1.18	0.58	3.13	4.30	0.44	3.78	3.23	2.00	0.30	18.94	1912	.....
(Government Record.)											Average............		28.01		27.69

RAINFALL AT BERKELEY—ELEVATION 320.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1887	....	....	....	....	....	....	1.66	9.41	0.98	2.53	0.06	0.04	.....	1887	18.79
1887-88	0.01	0	0.40	0	0.76	2.94	5.84	1.92	4.50	0.20	0.42	0.50	17.49	1888	20.49
1888-89	T.	0	0.59	0.02	2.71	3.79	0.78	0.54	7.58	0.72	1.50	0.06	18.29	1889	31.96
1889-90	0	0	0	5.80	2.39	12.59	11.16	5.70	4.74	2.18	1.44	T.	46.00	1890	28.79
1890-91	0	T.	0.25	0	0	3.32	1.13	10.68	3.17	3.42	1.61	0.38	23.96	1891	28.98
1891-92	0.44	0	0.74	0.18	1.01	6.22	2.34	4.20	3.60	1.68	2.97	0	23.38	1892	28.85
1892-93	0.01	0	0.07	1.99	5.35	6.64	3.90	3.28	6.19	1.62	0.26	0	29.91	1893	23.99
1893-94	0	0	0.38	0.52	5.22	2.62	9.54	3.77	0.91	0.57	2.01	1.11	26.65	1894	36.79
1894-95	0	0	1.61	3.29	1.35	12.63	10.88	3.25	2.64	2.30	1.06	0	39.01	1895	25.50
1895-96	0.04	0	1.28	0.07	1.78	2.20	11.40	0.36	2.93	6.72	0.94	0	27.72	1896	35.99
1896-97	T.	0.90	0.76	1.91	5.15	4.92	3.71	4.68	5.97	0.44	0.20	0.30	28.94	1897	22.27
1897-98	0	0	0.20	2.48	1.58	2.71	1.54	3.28	0.31	0.19	1.87	0.24	14.40	1898	12.47
1898-99	0	0.04	0.93	1.88	0.97	1.22	5.90	0.22	13.19	1.56	1.70	0.05	27.66	1899	37.19
1899-00	0	T.	0	5.26	5.85	3.46	4.18	1.02	3.00	1.58	0.91	0.08	25.34	1900	19.12
1900-01	0	0.02	0.05	1.41	5.04	1.83	5.86	5.91	0.91	3.06	1.02	0	25.11	1901	23.38
1901-02	0	0	1.30	0.68	3.16	1.48	1.36	10.47	4.17	1.55	1.69	0	25.86	1902	28.49
1902-03	0	T.	0	2.35	3.21	3.69	5.17	2.05	7.81	1.11	0.02	T.	25.41	1903	24.74
1903-04	0	0	0	0.50	5.89	2.19	1.40	10.45	11.04	2.10	0.02	T.	33.59	1904	37.17
1904-05	0	0.07	4.44	3.39	2.23	2.03	5.58	2.56	4.25	1.37	3.43	0	29.35	1905	20.87
1905-06	0	0	0	0	1.46	2.22	6.92	3.96	9.05	0.74	2.56	0.64	27.75	1906	32.96
1906-07	0	0.04	0.17	T.	1.64	7.24	5.02	5.36	10.76	0.36	0.04	1.24	31.87	1907	29.30
1907-08	0	0	0.06	1.54	0.08	4.84	5.44	4.35	1.37	0.30	1.17	0.01	19.16	1908	18.16
1908-09	0	0	0.09	0.98	1.83	2.62	13.11	9.26	3.64	0.02	0	0	31.55	1909	38.82
1909-10	0	0	0.78	1.34	3.43	7.24	3.38	1.85	3.82	0.41	0.01	0.02	22.28	1910	12.82
1910-11	0	0	0.06	0.60	0.87	1.80	15.99	4.05	5.17	1.56	0.27	0.04	30.41	1911	30.78
1911-12	T.	0	T.	0.73	0.46	2.51	3.65	0.54	2.96	1.47	1.56	0.85	14.73	1912	.....
										Average	.....	.....	26.63		26.75

(Weather Bureau.)

RAINFALL AT BOULDER CREEK—ELEVATION 470.

Santa Cruz County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1888-89	*0.01	*0.07	0.51	0	11.07	9.69	1.24	1.80	19.58	0.39	4.78	0	*49.14	1899	95.76
1889-90	0	0	0	19.68	9.56	38.73	29.40	10.62	11.77	2.29	1.60	0	123.65	1890	65.68
1890-91	0	0	0.30	0	0.25	9.45	2.46	34.03	5.57	6.81	2.40	0	61.27	1891	65.58
1891-92	0.08	0	1.17	0.03	1.06	11.97	4.60	9.51	11.29	1.99	6.03	0	47.73	1892	69.91
1892-93	0	0	0.39	2.20	12.79	21.11	10.04	9.57	16.91	3.49	0.65	0	77.15	1893	46.96
1893-94	0	0	0.57	0.54	0.60	4.59	14.92	13.87	2.11	2.44	3.26	0.39	43.29	1894	78.60
1894-95	0	0	2.62	6.70	1.76	30.53	12.56	4.40	5.89	3.55	1.83	0	*69.84	1895	*37.01
1895-96	0	0	0.17	0.65	3.08	4.88	26.86	0.24	4.25	8.47	1.81	0	50.41	1896	66.81
1896-97	0.07	0.94	0.37	2.57	10.93	10.30	3.17	10.41	11.56	0.69	0	0.71	51.72	1897	35.68
1897-98	0	0	T.	4.12	1.26	3.76	1.91	8.26	1.06	0.60	2.82	0.46	24.25	1898	21.19
1898-99	0	0	2.06	1.07	0.62	2.33	20.15	0.62	24.49	1.64	0.24	2.53	55.75	1899	72.20
1899-00	0	0	0	9.18	7.09	6.26	11.06	0.93	5.49	1.75	1.34	0	43.10	1900	41.79
1900-01	0	0	0.05	4.70	13.13	3.34	12.09	11.53	1.65	5.48	2.52	0	54.49	1901	44.70
1901-02	0	0	1.68	2.17	6.03	1.55	3.35	25.42	8.54	4.13	1.15	0.50	54.52	1902	57.13
1902-03	0	0	0	4.16	6.52	3.36	11.14	4.66	14.90	2.94	0	0	47.68	1903	48.64
1903-04	0	0	0	1.46	12.61	0.93	2.98	18.33	17.20	4.02	0.37	0	57.90	1904	67.51
1904-05	T.	0.38	9.10	8.70	1.99	4.44	8.58	10.49	8.57	2.07	6.02	0	60.34	1905	43.78
1905-06	0	0	T.	0	4.97	3.08	26.71	10.00	18.96	1.63	7.23	1.00	73.58	1906	86.36
1906-07	0	0	0.21	0	4.57	16.05	13.87	3.62	25.28	0.82	0.14	0.69	65.25	1907	56.79
1907-08	0	0.03	0.49	3.52	0	8.33	7.22	10.68	2.01	0.56	0.89	0	33.73	1908	31.03
1908-09	0	0	0.10	1.14	2.63	5.80	39.42	15.29	8.48	0	0	0.17	73.03	1909	82.22
1909-10	0	0.03	1.34	1.56	3.50	12.43	8.40	4.22	10.46	1.21	0	0	43.15	1910	29.03
1910-11	0	0	T.	1.72	0.77	2.25	33.95	6.26	10.39	4.04	0.53	0	59.91	1911	61.65
1911-12	0	0	0	0.25	1.25	4.98	7.48	0.57	7.87	3.57	2.77	0.75	29.49	1912	.....
											Average............		56.27		56.78

*Interpolated data.

From records of U. S. Weather Bureau.

RAINFALL AT CALAVERAS—ELEVATION 600.
Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1874-75	0	0	0	4.10	4.57	0.18	5.69	0.59	1.15	0	0	0	16.28	1875	23.65
1875-76	0	0	0	0.35	11.05	4.82	6.82	6.80	8.55	1.75	0.36	0	40.50	1876	27.26
1876-77	0	0	0	2.83	0.15	0	6.50	0.67	1.38	0.62	0	0	12.15	1877	13.07
1877-78	0	0	0	0.28	1.23	2.39	10.24	14.88	0	0	0	0	29.02	1878	26.89
1878-79	0	0	0.25	0.72	0.37	0.43	4.66	3.04	5.79	3.54	2.48	0.15	21.43	1879	29.33
1879-80	0	0	0	1.35	2.99	5.33	3.41	3.00	2.30	8.24	1.07	0	27.69	1880	29.39
1880-81	0	0	0	0.04	0.69	10.64	4.60	4.90	2.22	1.35	0.05	0.54	25.03	1881	19.73
1881-82	0	0	0.21	0.43	1.83	3.60	2.34	2.91	7.06	3.48	0.45	0.01	22.32	1882	23.59
1882-83	0	0	0.46	1.88	2.19	2.81	1.17	1.94	4.33	3.16	3.46	0	21.40	1883	18.09
1883-84	0	0	0.33	1.73	0.84	1.13	5.51	9.81	9.30	6.87	0.39	1.35	37.26	1884	47.38
1884-85	0	0.10	0.25	1.80	0.02	11.98	2.91	0.29	0.47	1.47	0.05	0.29	19.63	1885	19.29
1885-86	0	0	0.10	0	10.95	2.76	8.11	1.37	2.02	6.35	0	0	31.66	1886	.....
1886-87	....	....	....	....	....	....	....	....	.....	.....	.....	.....	.....	1887	.....
1887-88	....	....	....	....	....	....	....	.....	.....	.....	.....	.....	.....	1888	.....
1888-89	0	0	0.50	0	4.17	3.32	0.64	1.07	6.63	1.06	2.48	0	19.87	1889	34.36
1889-90	0	0	0	5.61	3.99	12.88	10.02	5.73	3.46	2.10	1.75	0	45.54	1890	28.82
1890-91	0	0	0.75	0	0.10	4.91	0.90	6.24	3.29	2.89	0.90	0.25	20.23	1891	26.31
1891-92	0	0	0.50	0.30	0.75	10.29	0.99	2.19	5.01	1.81	3.20	0.20	25.24	1892	30.62
1892-93	0	0	0	1.75	8.39	7.08	5.71	3.86	8.35	3.15	0.91	0	39.20	1893	28.74
1893-94	0	0	0.15	0.30	2.72	3.59	8.12	9.64	2.63	1.05	2.04	0.57	30.81	1894	42.17
1894-95	0	0	1.83	3.27	1.00	12.02	9.13	4.02	3.00	2.75	1.61	0	38.63	1895	26.71
1895-96	0	0	0.31	0.87	2.36	2.66	8.41	0.52	2.44	6.53	1.72	0	25.82	1896	31.93
1896-97	0	0.55	0.30	2.02	4.97	4.47	2.64	7.61	7.47	0.90	0	0.27	31.20	1897	23.96
1897-98	0	0	0	1.51	1.11	2.45	1.64	3.31	0.91	0.50	1.67	0.27	13.37	1898	13.47
1898-99	0	0	0.61	1.32	1.08	2.16	4.53	0	9.83	1.28	1.17	0	21.98	1899	31.03
1899-00	0	0	0	5.68	5.04	3.50	3.35	1.45	2.83	2.80	1.19	0	25.84	1900	25.04
1900-01	0	0	0	4.16	7.11	2.15	4.19	6.69	1.88	2.76	1.72	0	30.66	1901	23.47
1901-02	0	0	0.80	1.75	2.01	1.67	1.58	7.24	5.25	1.95	1.02	0	23.27	1902	24.88
1902-03	0	0	0	1.80	4.25	1.79	6.15	2.09	7.60	0.85	0.42	0	24.95	1903	23.78
1903-04	0	0	0	0.18	5.18	1.31	1.73	7.94	6.89	4.01	0.25	0	27.49	1904	32.08
1904-05	0	0.62	3.27	2.41	1.73	3.23	3.20	3.78	5.68	1.47	3.33	0	28.72	1905	22.29
1905-06	0	0	0	0	2.88	1.95	8.64	3.90	6.77	1.52	1.61	0.77	28.04	1906	33.30
1906-07	0	0	0.33	0	1.16	8.60	5.84	2.13	14.41	0.24	0.01	0.26	32.98	1907	30.27
1907-08	0	0	0	0.86	0.12	6.40	3.10	3.54	1.13	0.26	1.93	0	17.34	1908	.....
1908-09	....	....	....	....	....	....	....	.....	.....	.....	.....	.....	.....	1909	.....
1909-10	....	....	....	....	....	....	....	.....	.....	.....	.....	.....	.....	1910	.....
1910-11	0	0	0	0.50	0.38	0.96	14.94	3.71	6.01	0.96	0.62	0.04	28.12	1911	31.59
1911-12	0	0	0.01	1.26	1.01	3.03	2.41	0.39	3.12	2.02	0.82	0.72	14.79	1912	.....
										Average............			26.42		27.18

Records of S. V. W. Co.

RAINFALL AT COYOTE RESERVOIR

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1896-97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....
1897-98	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.51	....	.....
1898-99	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.37	....	.....
1899-00	.....	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	16.22	....	.....
1900-01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28.59	....	.....
1901-02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.13	....	.....
1902-03	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	16.09	....	.....
1903-04	.....	.....	.....	.....	.....	.....	.....	....	....	....	....	....	....	....	....
											Average	....	18.15		

(S. V. W. Co. R-24.)

RAINFALL AT CRYSTAL SPRINGS COTTAGE—ELEVATION 300.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1894-95	0	0	2.00	2.22	1.34	13.30	12.88	4.34	3.12	1.85	1.09	0	42.14	1895	28.22
1895-96	0	0	0.40	0.21	1.55	2.78	12.68	0.42	2.00	6.69	1.64	0	28.37	1896	38.02
1896-97	0	0.33	0.42	1.78	6.26	5.80	2.48	7.76	7.62	0.46	0.04	0	32.95	1897	25.49
1897-98	0	0	0	2.66	1.34	3.13	1.98	4.73	1.04	0.22	2.29	0.42	17.81	1898	15.86
1898-99	0	0	1.80	0.98	0.76	1.64	6.28	0.41	15.18	1.02	0.67	1.20	29.94	1899	40.21
1899-00	0	0.14	0	5.03	5.89	4.39	7.11	1.57	3.92	2.08	0.70	0.04	30.87	1900	28.76
1900-01	0	0	0.45	3.03	6.26	3.60	6.23	7.56	1.59	3.08	1.84	0	33.64	1901	27.87
1901-02	0	0	1.07	1.21	3.18	2.11	2.84	11.05	6.73	2.34	1.08	0.06	31.67	1902	32.22
1902-03	0	0	0	2.33	3.63	2.16	8.76	2.95	8.48	1.76	0	0	30.07	1903	33.77
1903-04	0	0	0	0.75	9.24	1.83	2.18	9.50	9.63	2.47	0.36	0.05	36.01	1904	37.07
1904-05	0.06	0.04	4.36	3.65	1.53	3.24	4.22	5.81	5.63	2.06	3.33	0	33.93	1905	26.42
1905-06	0	0	0	0	2.53	2.84	9.02	4.71	9.22	1.37	2.11	0.36	32.16	1906	37.80
1906-07	0	0	0.13	0	2.03	8.85	7.07	4.42	17.00	0.54	0.34	0.87	41.25	1907	37.32
1907-08	0	0	0	2.11	0	4.97	4.23	8.03	2.35	0.71	0.86	0	23.26	1908	22.18
1908-09	0	0	0.18	0.88	1.88	3.06	17.67	10.92	5.55	0	0	0	40.14	1909	45.43
1909-10	0	0	0.77	1.19	2.87	6.46	6.14	2.04	4.36	0.52	0	0	24.35	1910	16.70
1910-11	0	0	0.11	1.14	0.76	1.63	23.48	4.69	7.73	1.70	0.40	0.14	41.78	1911	43.21
1911-12	0	0	0	0.59	0.97	3.51	3.57	0.47	4.38	2.47	2.40	0.54	18.90	1912	.....
											Average	....	31.62		31.56

Records S. V. W. Co.

RAINFALL AT GILROY—ELEVATION 193.

Santa Clara County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1874	.....	.....	.....	.....	.....	.....	5.22	2.04	3.15	0.95	0.16	0	.....	1874	17.20
1874-75	0	0	0	3.55	2.09	0.04	7.70	0.75	0.69	0	0	0.30	15.12	1875	23.07
1875-76	0	0	0	0	11.75	1.88	6.75	3.97	5.93	0.76	0	0	31.04	1876	18.66
1876-77	0	0	0	1.25	0	0	3.75	0	0.82	0.27	0.44	0	6.53	1877	8.08
1877-78	0	0	0	0.10	1.14	1.56	8.89	11.48	3.24	1.62	0	0	28.03	1878	27.23
1878-79	0	0	0	0.88	0.70	0.42	3.80	4.02	3.98	1.47	1.34	0.15	16.76	1879	21.07
1879-80	0	0	0	1.00	1.68	3.63	2.36	1.74	1.84	9.48	0.65	0	22.38	1880	28.86
1880-81	0	0	0	0	0.46	12.33	6.84	1.95	1.14	0.59	0	0.11	23.42	1881	14.59
1881-82	0	0	0.34	0.46	0.81	2.35	1.28	2.17	5.61	0.72	0.25	0.10	14.09	1882	15.83
1882-83	0	0	1.46	2.22	1.64	0.38	2.28	1.02	2.77	1.19	2.23	0	15.19	1883	11.88
1883-84	0	0	0.27	1.01	0.33	0.78	2.94	6.65	7.24	3.80	0.34	1.24	24.60	1884	32.95
1884-85	0	0	0.12	1.73	0.06	8.83	2.03	0.09	0.28	1.48	0	0.12	14.74	1885	13.33
1885-86	0.05	0.11	0	0	6.77	2.40	6.09	0.32	1.17	4.32	0.22	0	21.45	1886	14.32
1886-87	0	0	0	0.78	0.33	1.09	0.90	5.14	0.82	2.05	0	0	11.11	1887	14.81
1887-88	0	0	0.43	0	1.15	4.32	5.35	0.77	3.92	0.40	0.44	0	16.78	1888	17.01
1888-89	0	0	0.32	0	3.71	2.10	0.46	1.00	4.22	0.63	2.00	0	14.44	1889	26.86
1889-90	0	0	0	5.36	2.98	10.21	10.50	5.62	1.89	0.64	0.55	0	37.75	1890	23.34
1890-91	0	0	0.20	0	0.10	3.84	0.75	6.76	0.97	2.18	0.04	0	74.84	1891	16.71
1891-92	0	0	0.03	0.07	0.11	5.80	4.71	1.90	4.18	0.90	1.21	0	18.91	1892	23.48
1892-93	0	0	0	1.19	5.40	3.99	3.11	4.34	4.80	1.35	0.32	0	24.50	1893	16.59
1893-94	0	0	0.06	0.02	0.72	1.87	4.71	3.04	0.66	0.55	1.28	0	12.91	1894	21.22
1894-95	0	0	1.04	1.26	0.24	8.44	10.39	1.79	2.54	1.90	1.21	0	28.81	1895	22.05
1895-96	0	0	0	1.27	1.04	1.91	10.06	0	2.06	4.02	4.34	0	24.70	1896	29.19
1896-97	0	1.00	0.09	1.88	3.75	1.99	2.05	4.97	5.53	0.45	0.02	0.09	21.82	1897	17.38
1897-98	0	0	0.05	1.94	0.35	1.93	0.98	2.27	1.24	0.32	1.28	0.08	10.44	1898	7.98
1898-99	0	0	0.15	0.40	0.33	0.93	6.00	0.32	9.80	0.51	1.00	0	19.44	1899	25.91
1899-00	0	0	0	2.40	3.09	2.79	2.22	0.34	1.65	1.60	0.45	0	14.54	1900	18.14
1900-01	0	0	0.01	1.59	9.29	0.99	2.44	3.95	1.29	2.07	1.54	0	23.17	1901	14.55
1901-02	0	0	0.15	0.86	1.96	0.29	1.16	8.28	3.61	1.83	0.27	0	18.41	1902	19.70
1902-03	0	0	0	1.43	1.85	1.27	3.31	1.97	6.44	1.21	0	0	17.48	1903	16.16
1903-04	0	0	0	0	2.95	0.28	1.03	6.40	5.94	1.66	0	0	18.26	1904	21.79
1904-05	0	0	2.01	2.07	0.76	1.92	3.54	4.39	4.84	0.79	2.93	0	23.25	1905	19.79
1905-06	0	0	0	0	1.90	1.40	11.35	3.46	7.77	1.27	2.21	0.06	29.42	1906	38.67
1906-07	0	0	0	0	2.29	10.26	3.46	1.73	10.24	0.41	0.12	0.47	28.98	1907	23.67
1907-08	0	0	T	1.80	0	5.44	2.83	1.97	1.24	0.45	0.52	0	14.25	1908	11.16
1908-09	0	0	0.02	0.25	1.93	1.95	12.80	6.41	4.41	0	0	0.04	27.81	1909	32.69
1909-10	0	0	0.16	0.54	2.00	6.33	5.79	1.18	3.07	0.40	0	0	19.47	1910	12.44
1910-11	0	0	0.05	0.54	0.41	0.97	6.63	2.19	6.19	1.99	0.34	0.07	19.38	1911	20.67
1911-12	0	0	0	0.58	0.64	2.04	2.68	0.17	4.00	2.89	0.84	0.03	13.87	1912	.....
											Average............		19.95		19.97

Records of U. S. Weather Bureau.

RAINFALL AT LICK OBSERVATORY—ELEVATION 4,209.

Santa Clara County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1881	.....	.....	.....	.....	.....	.....	3.51	5.99	1.13	0.98	0.09	0.33	.....	1881	23.09
1881-82	0	0	0.10	0.33	0.91	9.72	3.55	2.90	5.40	4.70	0.48	1.06	29.15	1882	29.63
1882-83	0	0	0	6.16	3.45	1.93	3.10	3.75	8.66	2.66	7.55	0	37.26	1883	32.05
1883-84	0	0	0.65	2.15	1.48	2.05	5.60	12.76	16.35	11.96	1.24	3.85	58.09	1884	90.12
1884-85	0	0.15	0.65	3.71	0.01	33.84	1.99	0.57	1.15	2.08	0.16	0.36	44.67	1885	18.23
1885-86	0	0	0.15	0.05	1.92	9.80	4.44	1.80	5.77	6.79	0.70	0	31.42	1886	25.26
1886-87	0	0	0	0.60	2.82	2.34	2.83	7.80	1.39	5.75	0.25	0.30	24.08	1887	30.93
1887-88	0.04	0	0.33	0.09	0.90	11.25	10.04	1.38	3.40	0.68	1.25	0.67	30.03	1888	25.46
1888-89	0	0.02	0.49	0.03	3.27	4.23	1.04	1.42	6.17	1.92	3.21	0.05	21.85	1889	35.84
1889-90	0	0	0	4.38	4.46	13.19	7.93	6.60	4.39	1.79	2.42	0	45.16	1890	29.92
1890-91	0	0	0.80	0.02	0.58	5.39	1.38	7.12	4.10	3.08	1.01	0.57	24.05	1891	28.07
1891-92	0	0	0.28	0.61	0.38	9.54	1.97	2.99	5.98	1.90	3.52	0.32	27.49	1892	34.16
1892-93	0	T	0.24	1.38	10.30	5.56	3.29	3.45	8.99	3.61	0.95	0.16	37.93	1893	29.18
1893-94	0	0	0.48	0.66	4.01	3.58	9.74	10.52	2.54	0.89	2.78	0.64	35.84	1894	44.49
1894-95	0.02	T	1.64	2.98	0.84	11.90	10.00	3.08	1.46	2.30	2.39	0	36.61	1895	25.72
1895-96	0.01	0	0.08	0.78	2.46	3.16	9.54	1.08	3.83	6.70	2.10	0.02	29.76	1896	36.64
1896-97	T	0.28	0.47	1.85	5.86	4.91	3.50	7.42	6.45	0.82	0.28	0.38	32.22	1897	24.38
1897-98	0	0	0.07	1.25	1.51	2.70	2.30	4.16	2.04	0.84	2.41	0.38	17.66	1898	17.11
1898-99	0	0	0.29	1.33	1.23	2.13	5.63	0.75	11.11	1.40	1.47	0.39	25.73	1899	36.32
1899-00	0	0.12	T	6.37	4.92	4.16	3.26	1.70	3.37	4.06	1.35	T	29.31	1900	27.30
1900-01	0.01	0.02	0.08	3.48	7.76	2.21	5.76	5.92	1.98	3.33	1.07	0.02	31.64	1901	25.90
1901-02	0	0.05	1.08	2.19	2.89	1.61	1.44	9.42	5.19	2.61	1.14	0	27.62	1902	27.97
1902-03	0	0	0	2.05	3.01	3.11	8.86	2.20	9.89	1.12	0.05	T.	30.29	1903	31.47
1903-04	0	0	T	0.29	7.67	1.39	1.98	9.53	8.06	4.38	0.45	0.03	33.78	1904	35.21
1904-05	T	0.05	2.33	2.51	2.05	3.84	4.04	4.19	5.91	1.36	2.27	0	28.55	1905	22.83
1905-06	0	0	0.02	0	3.00	2.04	11.66	5.76	9.82	1.83	3.15	1.15	38.43	1906	45.93
1906-07	0	T	0.28	0.05	1.92	10.31	9.74	4.76	13.80	1.14	0.42	0.92	43.34	1907	40.36
1907-08	T	0	0.01	1.62	0.18	7.77	5.02	4.26	1.95	0.70	2.39	0.02	23.92	1908	19.93
1908-09	0	0	0	0	2.63	2.96	18.18	9.49	4.05	0	0.11	0	37.42	1909	43.06
1909-10	0	0	0	1.77	2.59	6.87	7.29	3.12	3.28	0.91	0.12	0.07	26.02	1910	18.85
1910-11	0.04	0	0.25	1.06	0.94	1.77	15.76	4.37	7.00	1.35	0.75	0	33.29	1911	34.12
1911-12	0	0	0	0.46	1.21	3.22	4.44	0.50	3.96	2.70	1.31	0.44	18.24	1912	....
											Average	....	31.96		31.92

Records of U. S. Weather Bureau.

RAINFALL AT LIVERMORE—ELEVATION 485.

Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1871	.....	.....	.....	.....	.....	.....	1.42	1.93	0.36	1.25	0.02	0	.....	1871	17.80
1871-72	0	0	0	T	1.13	11.69	2.15	2.69	0.65	0.43	0	0.32	19.06	1872	11.33
1872-73	0	T	0	0	1.22	3.87	1.04	3.73	0.68	0.15	0	0	10.69	1873	11.20
1873-74	0	0	0	0.42	0.70	4.48	2.96	1.03	1.34	0.95	0.32	0.06	12.26	1874	10.86
1874-75	0	0	0.30	1.67	2.03	0.20	5.40	1.20	0.35	0	0	0.52	11.67	1875	16.32
1875-76	0	0	0	0	7.23	1.62	2.68	3.01	4.39	0.73	0.33	0	19.99	1876	12.50
1876-77	0	0	0	1.26	0.10	0	2.47	0.56	1.10	0.13	0.39	0	6.01	1877	7.94
1877-78	0	0	0	1.27	1.29	0.73	4.61	6.73	2.01	0.96	0.06	0	17.66	1878	15.09
1878-79	0	0	0	0.24	0.31	0.17	2.83	1.78	2.49	0.75	1.34	0.20	10.11	1879	13.22
1879-80	0	0	0	0.83	1.06	1.94	1.48	1.80	1.45	6.51	0.91	0	15.98	1880	20.55
1880-81	0	0	0	0	0.65	7.75	2.40	2.62	1.06	1.93	0	0.04	16.45	1881	10.88
1881-82	0	0	T	0.08	0.78	1.97	1.07	1.72	4.85	1.03	0.20	0	11.70	1882	12.59
1882-83	0	0	0.34	1.52	1.48	0.38	2.38	0.63	3.45	1.50	2.18	0	13.86	1883	13.02
1883-84	0	0	0.35	1.52	0.57	0.44	4.03	5.29	5.92	2.70	0.20	1.73	22.75	1884	27.65
1884-85	0	0.10	0.30	1.14	0.02	6.22	1.72	0.36	0.78	1.29	0.08	0	12.01	1885	12.42
1885-86	0	0	0.05	0	6.20	1.94	4.20	0.24	1.18	2.36	0	0	16.17	1886	10.19
1886-87	0.40	0	0	0.30	0.70	0.81	0.90	6.23	0.23	1.60	0	0	11.17	1887	13.88
1887-88	0	0	0.80	0	0.61	3.51	3.20	0.94	2.51	0.60	0.66	0.30	13.13	1888	14.98
1888-89	0	0	0.76	0	3.80	2.21	0.46	0.67	5.15	0.51	2.25	T	15.81	1889	24.56
1889-90	0	0	0	3.94	2.95	8.63	5.24	3.71	2.85	0.86	0.48	0	28.66	1890	17.65
1890-91	0	0	1.20	0	0	3.31	0.54	4.18	2.50	1.88	0.40	0.15	14.16	1891	15.82
1891-92	0	0	1.32	0.05	0.38	4.42	0.84	1.08	3.96	0.90	1.30	T	14.25	1892	22.42
1892-93	0	0	0.45	1.65	4.97	7.27	3.02	3.12	3.68	1.40	0.73	0	26.29	1893	15.68
1893-94	0	0	0	0	1.59	2.14	4.97	5.36	0.81	0.58	1.19	0.52	17.16	1894	25.09
1894-95	0	0	1.45	1.15	0.50	8.56	6.83	1.56	1.81	1.26	1.25	0	24.37	1895	16.73
1895-96	0	0	0.22	0.83	1.69	1.28	7.16	0.17	1.50	3.11	0.39	0	16.35	1896	19.82
1896-97	0	0.73	0.55	1.48	3.02	1.71	1.89	3.54	4.04	0.24	0	0.08	17.28	1897	13.11
1897-98	0	0	0.06	1.43	0.52	1.31	1.47	1.78	0.78	0.45	0.96	0.35	9.11	1898	8.95
1898-99	0	0	0.95	0.35	0.25	1.61	2.60	0.08	2.70	0.33	0.18	0.22	9.27	1899	12.98
1899-00	0	0	0	2.52	2.49	1.86	2.44	0.34	1.11	0.86	1.10	0	12.72	1900	13.70
1900-01	0	0	0.18	1.93	4.48	1.26	2.69	4.85	0.95	1.80	1.58	0	19.72	1901	*18.27
1901-02	0	0	0.63	0.83	1.99	* 2.95	*3.02	3.62	2.69	0.75	0.32	0	*16.80	1902	*13.94
1902-03	T	0.13	0	0.47	2.07	0.87	3.19	0.94	5.65	0.81	0.12	0	14.25	1903	13.46
1903-04	0	0	0	T	2.16	0.59	0.89	4.18	3.71	1.56	0.24	T	13.33	1904	15.72
1904-05	T	0.32	1.62	1.00	0.78	1.42	2.43	2.30	3.12	0.93	1.89	0	15.81	1905	13.46
1905-06	0	0	T	0	1.61	1.18	5.56	2.67	5.18	0.95	1.61	0.56	19.32	1906	24.55
1906-07	T	0	0.20	0.03	1.34	6.45	3.22	1.86	8.85	0.47	0.16	0.56	23.14	1907	19.87
1907-08	0	0	T	0.81	0.04	3.90	2.27	1.35	0.75	0.28	0.53	T	9.93	1908	7.63
1908-09	T	0	0.03	0.27	0.60	1.55	10.18	3.96	1.94	0	T	0.05	18.58	1909	24.95
1909-10	0	0	0.62	0.75	1.68	5.77	2.50	1.14	1.90	0.10	T	0.04	14.50	1910	7.49
1910-11	T	0	0.10	0.29	0.10	1.32	12.60	1.42	4.45	0.69	0.24	0.07	21.28	1911	21.90
1911-12	T	0	T	0.43	0.29	1.71	2.66	0.20	1.99	0.73	0.94	0.65	9.60	1912	.....
											Average	....	15.67		15.61

*Interpolated data.

From records of U. S. Weather Bureau.

RAINFALL AT LOS GATOS—ELEVATION 600.

Santa Clara Co., Cal.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1885	.....	.....	.....	.....	.....	.....	1.50	0.15	0.54	1.90	0	0	.....	1885	24.10
1885-86	0	0	0	0.06	13.31	6.64	11.30	1.34	2.82	7.12	0.43	T	43.02	1886	26.08
1886-87	0.04	0	0.07	0.92	0.68	1.36	1.52	15.31	1.68	2.75	0.03	T	24.36	1887	30.07
1887-88	T	0	0.46	0.05	1.36	6.91	5.73	1.47	6.74	0.07	1.00	0.38	24.17	1888	30.45
1888-89	0	0	0.59	6.19	3.88	4.40	0.66	0.45	10.61	0.74	2.35	0	29.87	1889	49.93
1889-90	0	0	0	10.85	4.33	19.94	16.45	7.83	5.27	1.25	1.30	0	67.22	1890	37.06
1890-91	0	0	0.19	0	0.03	4.74	1.10	17.50	4.65	3.13	0.52	0.11	31.97	1891	35.45
1891-92	0	0	0.48	0.03	0.64	7.29	1.76	3.43	5.62	0.81	3.05	0	23.11	1892	44.52
1892-93	0	0	0	1.19	13.71	14.95	8.18	5.78	9.15	2.57	0.71	T	56.24	1893	30.17
1893-94	0	0	0.23	0.31	1.08	2.16	6.98	5.22	1.30	1.50	2.25	0.22	21.25	1894	40.20
1894-95	T	0	1.34	2.87	0.75	17.77	14.67	1.95	3.96	2.87	1.00	0	47.18	1895	29.74
1895-96	0	0	0.24	1.59	1.24	2.22	17.39	0.08	3.66	7.25	0.81	0	34.48	1896	44.96
1896-97	0	0.77	0.39	1.95	6.26	6.40	3.07	6.50	6.60	0.40	0	0.15	32.49	1897	21.31
1897-98	0	0	0.06	1.84	0.88	1.81	1.57	6.38	0.82	0.34	1.25	0.23	15.18	1898	14.72
1898-99	0	0	1.77	0.94	0.46	0.96	7.82	0.44	11.10	0.60	0.83	0.01	24.93	1899	33.65
1899-00	0	T	0	5.55	3.84	3.46	5.40	0.45	2.93	1.73	0.88	T	24.24	1900	25.60
1900-01	T	0	0.05	2.39	9.27	2.50	8.96	9.74	1.09	5.59	1.76	T	41.35	1901	33.21
1901-02	T	T	0.90	1.10	3.34	0.73	1.28	14.49	7.59	2.63	1.17	0	33.23	1902	36.75
1902-03	0	0	T	2.80	4.90	1.89	5.93	2.51	10.17	0.78	0	T	28.98	1903	25.91
1903-04	0	0	0	0.84	4.94	0.74	1.20	9.14	8.54	3.66	0.19	T	29.25	1904	36.48
1904-05	0	0.57	5.97	2.83	1.15	3.23	4.98	5.86	6.55	1.21	3.53	0	35.88	1905	26.77
1905-06	0	0	T	T	3.00	1.64	13.65	4.71	10.81	1.01	2.98	0.29	38.13	1906	46.89
1906-07	0	0	0.25	T	1.76	11.39	8.36	2.11	18.13	0.42	0.13	0.87	43.42	1907	39.52
1907-08	0	T	0.06	1.41	0.03	8.00	3.80	5.85	2.31	0.35	0.57	0	22.38	1908	17.98
1908-09	0	0	0.07	0.40	1.73	2.90	23.90	10.83	4.85	0	0	0.07	44.75	1909	51.77
1909-10	0	0	1.15	0.63	1.71	8.63	6.94	2.04	4.28	0.36	0	0.04	25.78	1910	16.58
1910-11	T	0	0.02	0.60	0.58	1.72	27.66	4.79	14.16	2.46	0.59	0.05	52.63	1911	53.62
1911-12	T	0	T	0.55	0.70	2.66	4.15	0.28	5.52	3.66	1.61	0.33	19.46	1912	.....
												Average............	33.89		33.46

From records of U. S. Weather Bureau.

RAINFALL AT LOWER CRYSTAL SPRINGS—ELEVATION 300 FEET.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1888-89	.....	.....	.....	.....	.....	.....	.....	....	....	....	....	....	22.53	1889	....
1889-90	.....	.....	.....	.....	.....	.....	.....	....	....	....	....	....	....	1890	....
1890-91	.....	.....	.....	.....	.....	.....	.....	....	....	....	....	....	....	1891	....
1891-92	0	0	0.07	0	1.15	5.20	2.93	1.93	4.51	1.19	1.67	0	18.65	1892	21.26
1892-93	0	0	0	1.32	3.60	4.11	3.19	4.07	8.60	2.64	0.47	0	28.00	1893	29.26
1893-94	0	0	0.40	0.59	5.93	3.37	9.40	5.59	1.80	1.01	0.79	0.24	29.12	1894	....
1894-95	.....	.....	1.39	3.33	.....	.....	.....	....	....	....	....	....	45.15	1895	....
1895-96	.....	.....	.....	.....	.....	.....	12.62	0.37	3.05	6.88	2.34	0.02	31.42	1896	40.09
1896-97	0	0.19	1.09	1.18	6.68	5.67	2.62	8.53	8.26	0.63	0.18	0.13	35.16	1897	26.91
1897-98	0	0	0	2.57	1.42	2.57	2.15	4.62	0.88	0.73	2.34	0.36	17.64	1898	16.04
1898-99	0	0	1.49	0.91	0.82	1.74	6.22	0.44	15.27	1.52	0.71	1.12	30.24	1899	38.27
1899-00	0	0.02	0	4.48	4.82	3.67	6.70	1.13	3.57	2.29	0.30	0	26.98	1900	27.20
1900-01	0	0	0.31	3.47	6.53	2.90	5.26	7.09	1.26	3.01	1.66	0	31.49	1901	24.71
1901-02	0	0	0.93	0.82	2.86	1.82	2.32	11.42	5.08	2.07	1.16	0.21	28.69	1902	33.29
1902-03	0	0	0	2.76	4.84	3.43	8.66	2.89	7.55	1.76	0	0	31.89	1903	32.58
1903-04	0	0	0	0.58	9.80	1.34	2.39	10.72	9.70	1.65	0.36	0	36.54	1904	39.59
1904-05	0	0.03	5.61	4.48	1.39	3.26	4.46	4.50	6.05	2.02	3.61	0	35.41	1905	27.05
1905-06	0	0	0	0	2.94	3.47	9.71	6.38	8.82	0.70	1.89	0.52	34.43	1906	37.45
1906-07	0	0	0.13	0	1.56	7.74	8.12	6.75	15.40	0.81	0.28	1.07	41.86	1907	40.47
1907-08	0	0	0	1.96	0	6.08	4.97	7.15	2.27	1.08	1.21	0.11	24.83	1908	23.25
1908-09	0	0	0.08	1.26	2.33	2.79	24.75	10.65	5.22	0	0	0	47.08	1909	54.78
1909-10	0	0	1.16	1.70	2.90	8.40	6.60	3.47	4.76	0.53	0.04	0.04	29.60	1910	20.24
1910-11	0	0	0.19	1.27	1.13	2.21	24.41	5.05	6.67	2.34	0.67	0.08	44.02	1911	47.07
1911-12	0	0	0	1.19	2.22	4.44	3.93	0.38	4.56	2.26	2.35	0.64	21.97	1912	....
											Average............		31.49		32.20

Records S. V. W. Co.

RAINFALL AT MENLO PARK—ELEVATION 64 FEET.

San Mateo County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1878	0	....	....	....	....	....	2.98	2.21	1.72	1.36	0.10	0	.....	1878	9.04
1878-79	0	T.	0	0	0.42	0.25	3.09	2.73	4.27	1.19	0.98	0.03	12.96	1879	18.39
1879-80	0	0	0	0.48	1.66	3.96	1.92	1.79	1.65	6.44	0.69	0	18.59	1880	22.01
1880-81	0	0	0	0	0.59	8.93	3.70	1.56	0.68	2.66	0	0.24	18.36	1881	11.88
1881-82	0	0	0	0.36	0.71	1.97	0.65	1.17	3.71	0.67	0.18	0	9.42	1882	10.07
1882-83	0	0	0.23	1.25	1.69	0.52	2.38	0.52	2.70	0.76	2.49	0	12.54	1883	10.91
1883-84	0	0	0.20	0.73	0.28	0.85	3.35	4.07	4.80	3.40	0	3.16	20.84	1884	25.92
1884-85	0	0.05	0.04	1.86	0.27	4.92	1.89	0.12	0.50	1.98	0.04	0	11.67	1885	13.03
1885-86	0	0	0.02	0.09	6.22	2.17	4.97	0.37	1.65	3.34	0.08	0	18.91	1886	13.17
1886-87	0.24	0	0	0.86	0.40	1.26	0.72	4.92	0.46	1.18	0.01	0	10.05	1887	10.52
1887-88	0	0	0.22	0	0.85	2.16	3.17	1.36	2.31	0.02	0.37	0.09	10.55	1888	14.61
1888-89	0	0	0.98	0	3.72	2.59	0.65	0.54	5.75	0.69	1.08	0	16.00	1889	26.90
1889-90	0	0	0	4.96	2.38	10.85	7.45	3.27	2.76	0.51	1.48	0	33.66	1890	18.26
1890-91	0	0	0.18	0	0	2.61	0.69	7.02	2.17	1.83	0.38	0.03	14.91	1891	18.12
1891-92	0	0	0.28	0	0.46	5.26	1.07	1.39	2.91	0.47	1.43	0	13.27	1892	19.65
1892-93	0	0	0	1.14	4.69	6.55	2.44	2.75	4.33	1.26	0.23	0	23.39	1893	14.60
1893-94	0	0	0.09	0.09	1.51	1.90	4.60	2.80	0.57	0	0.99	0.01	12.56	1894	22.24
1894-95	0	0	1.65	1.51	0.46	9.65	7.12	1.59	2.30	1.44	0.36	0	26.08	1895	16.55
1895-96	0	0	0	1.16	1.45	1.13	6.76	0	2.15	3.65	0.45	0	16.75	1896	23.33
1896-97	0	0.85	0.53	1.13	4.67	3.14	1.69	3.92	4.20	0.13	0	0	20.26	1897	14.24
1897-98	0	0	0	1.91	0.76	1.63	1.38	2.24	0.58	0.15	0.63	0	9.28	1898	9.01
1898-99	0	0	2.00	0.73	0.31	0.99	3.62	0.42	6.67	0.34	0.07	0.05	15.20	1899	19.39
1899-00	0	0.05	0	3.08	3.22	1.87	3.69	0.52	1.46	1.00	0.66	0.05	15.60	1900	15.98
1900-01	0	0	0	2.00	4.61	1.99	2.97	5.27	0.74	1.08	0.97	0	19.63	1901	14.13
1901-02	0	0	0.55	0.55	1.53	0.47	1.58	4.98	3.48	1.20	0.97	0	15.31	1902	16.19
1902-03	0	0	0	1.36	1.85	0.77	4.14	1.68	6.20	1.10	0	0	17.10	1903	16.31
1903-04	0	0	0	0.15	2.39	0.65	0.86	5.21	5.05	1.62	0.23	0	16.16	1904	20.13
1904-05	0	0.11	2.41	2.37	0.87	1.40	2.21	2.54	2.23	1.44	2.08	0	17.66	1905	14.35
1905-06	0	0	T.	0	2.22	1.63	5.79	2.62	5.56	0.81	1.33	1.07	21.03	1906	23.08
1906-07	0	0	0.21	0	0.90	4.79	*3.22	2.69	8.75	0.23	T.	0.31	*21.10	1907	*20.99
1907-08	0	0	0.20	1.13	0	4.46	3.54	3.11	1.36	0.18	0.33	0	14.31	1908	12.87
1908-09	0	0	0	0.45	1.17	2.73	11.91	5.79	2.65	0	0	0	24.70	1909	29.05
1909-10	0	0	1.12	0.57	1.36	5.65	3.37	0.97	2.49	0.18	0	0	15.71	1910	8.80
1910-11	0	0	0.06	0.28	0.20	1.25	14.76	2.34	4.66	0.92	0.30	T.	24.77	1911	24.65
1911-12	0	0	0	0.20	0.15	1.32	1.67	0.13	2.69	1.45	0.92	0.75	9.28	1912	.....
										Average			16.99		17.01

*Interpolated data.

Records of U. S. Weather Bureau.

RAINFALL, MILLS COLLEGE—ELEVATION 200 FEET.

Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1893	....	....	....	....	....	....	3.78	3.54	6.00	1.46	0	0	.....	1893	24.75
1893-94	0	0	0.50	0.16	6.86	2.45	10.36	4.15	1.04	0.73	1.47	0.80	28.52	1894	37.31
1894-95	0	T.	1.97	2.88	1.01	12.90	9.79	3.60	2.39	1.47	1.18	0	37.19	1895	23.19
1895-96	0	0	0.64	0.28	1.91	1.93	11.90	0.40	2.02	5.60	1.14	0	25.82	1896	33.98
1896-97	0	0.95	0.80	1.51	6.07	3.59	3.43	6.60	6.64	0.47	0.18	0.21	30.45	1897	24.98
1897-98	0	0	0.08	2.99	1.48	2.90	1.42	3.10	0.24	0.32	1.45	0.46	14.44	1898	12.29
1898-99	0	0.03	1.10	1.49	1.04	1.64	4.49	0.15	13.62	0.86	1.51	0.22	26.15	1899	34.14
1899-00	0	0	0	4.60	5.44	3.25	4.09	1.61	2.98	1.62	0.73	T.	24.32	1900	20.02
1900-01	0	0	T.	2.09	5.11	1.79	6.08	5.90	1.35	2.99	1.12	0	26.43	1901	23.39
1901-02	0	T.	0.65	0.73	3.00	1.57	1.32	9.25	3.92	1.89	1.15	0	23.48	1902	27.73
1902-03	0	T.	0	3.03	3.44	3.73	5.68	1.99	6.68	1.14	0	0	25.69	1903	24.35
1903-04	0	0	0	0.52	7.02	1.32	1.97	9.96	9.19	1.79	0.35	0.07	32.19	1904	33.91
1904-05	T.	0.12	3.82	3.12	1.71	1.81	4.84	3.62	4.84	1.60	2.32	0	27.80	1905	20.97
1905-06	0	0	T.	T.	1.63	2.12	5.92	4.74	8.22	0.62	2.31	0.72	26.28	1906	31.37
1906-07	0	0	0.26	0.02	2.05	6.51	5.46	6.42	10.28	0.49	0.13	1.43	33.05	1907	30.27
1907-08	0	0	0.01	1.43	0.12	4.50	4.45	4.51	1.25	0.47	1.06	0	17.80	1908	16.92
1908-09	0	0	0.16	0.88	2.03	2.11	15.07	7.64	3.89	0	0	0	31.78	1909	39.01
1909-10	0	0	0.93	1.20	3.51	6.77	3.31	1.99	3.37	0.68	0.04	0.02	21.82	1910	12.31
1910-11	T.	0	0.06	0.37	0.82	1.65	16.24	3.59	5.47	1.60	0.37	0.11	30.28	1911	.....
1911-12	Broken Record			0.45	0.60	3.09	3.23	0.49	3.00	1.68	2.06	0.63	.....	1912	.....
										Average	....		26.86		26.16

Records of U. S. Weather Bureau.

RAINFALL AT MONTEREY—ELEVATION 15 FEET.

Monterey County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1847	....	....	....	....	....	....	....	....	....	....	0.03	0	.....	1847	....
1847-48	0	0	0	1.10	3.10	0	1.70	2.20	2.40	0.65	2.50	0.50	14.15	1848	....
1848-49	0.50	0	....	....	....	....	....	....	....	....	0.03	0	....	1849	....
1849-50	0	0	0	0.01	0.61	3.45	2.95	2.00	1.30	0.33	0	0	10.65	1850	10.19
1850-51	0	0	0.02	0	0.61	2.98	....	....	....	....	....	....	....	1851	....
1851-52	0.01	0	0.01	0.20	0.91	4.50	0.40	0.30	6.12	0.92	0.10	0.16	13.63	1852	....
1852-53	0	0	....	....	....	....	....	....	....	....	....	....	....	1853	....
1853-54	....	....	....	....	....	....	....	....	....	....	....	....	....	1854	....
1854-55	....	....	....	....	....	....	....	....	....	....	....	....	....	1855	....
1855-56	....	....	....	....	....	....	....	....	....	....	....	....	....	1856	....
1856-57	....	....	....	....	....	....	....	....	....	....	....	....	....	1857	....
1857-58	....	....	....	....	....	....	....	....	....	....	....	....	....	1858	....
1858-59	....	....	....	....	....	....	....	....	....	....	....	....	....	1859	....
1859-60	....	....	....	....	3.03	2.86	0.98	0.54	7.02	2.60	2.05	0.17	....	1860	....
1860-61	0.40	....	....	0.70	0.11	....	....	....	....	....	0.10	....	....	1861	....
1861-62	....	....	....	....	....	....	....	....	....	....	....	....	....	1862	....
1862-63	....	....	....	....	....	....	....	....	....	....	....	....	....	1863	....
1863-64	....	....	....	....	2.01	0.69	4.28	0.04	1.60	1.23	1.35	0.06	....	1864	17.08
1864-65	0	0.10	0	0.30	4.13	3.99	1.94	1.66	0.31	0.36	0.31	0	13.10	1865	8.16
1865-66	0.10	0	0.17	0.17	1.78	1.36	6.07	1.16	3.13	0.99	0.86	0.14	15.93	1866	21.56
1866-67	0	0.02	0	0	2.33	6.86	3.61	4.23	3.31	....	....	....	....	1867	....
1867-68	....	....	0.09	....	2.76	6.71	7.65	1.66	4.78	1.04	0.11	0.25	....	1868	....
1868-69	0.06	....	....	....	1.42	4.30	3.83	4.13	2.69	0.94	....	0.03	....	1869	....
1869-70	0.01	....	....	1.36	0.72	2.42	1.13	3.80	1.91	1.44	0.81	0	....	1870	....
1870-71	....	....	....	0.46	1.19	2.37	1.44	2.64	0.31	....	0.50	0.03	....	1871	....
1871-72	....	....	....	....	....	11.42	0.33	3.45	1.08	0.66	0.31	0.65	....	1872	....
1872-73	....	0.16	0.05	....	....	....	....	....	....	....	....	....	....	1873	....
1873-74	....	....	....	....	....	....	....	....	....	....	....	....	....	1874	....
1874-75	....	....	....	....	....	....	....	....	....	....	....	....	....	1875	....
1875-76	....	....	....	....	....	....	....	....	....	....	....	....	....	1876	....
1876-77	....	....	....	....	....	....	....	....	....	....	....	....	....	1877	....
1877-78	....	....	....	....	....	....	9.47	11.68	3.42	2.49	0	0	....	1878	28.55
1878-79	0	0	0	0.54	0.18	0.77	3.54	2.36	2.32	1.77	0.41	0	11.89	1879	15.43
1879-80	0	0	0	0.54	1.00	3.49	*3.03	2.55*	1.05	5.31	0.77	0	17.74	1880	18.58
1880-81	0	0	0	0	0.40	5.47	2.70	2.07	1.55	1.37	0	0.20	13.76	1881	11.82
1881-82	0	0	0	0.60	1.20	2.13	1.50	2.52	5.64	1.57	0	0	15.16	1882	14.71
1882-83	0	0	0.22	1.67	1.20	0.39	2.60	2.22	5.68	1.42	0.99	0.10	16.49	1883	15.46
1883-84	0	0	0.19	0.71	0.39	1.16	2.60	4.34	6.08	3.75	0.36	1.80	21.38	1884	26.47
1884-85	0	0.07	0.03	1.81	0.30	5.33	1.22	0.09	0.40	1.70	0.20	0.03	11.18	1885	11.92
1885-86	0	0	0	0	6.55	1.73	3.09	1.14	2.52	3.39	0.08	0	18.50	1886	12.30
1886-87	0	0	0	0.70	0.78	0.60	0.35	4.92	0.60	1.16	0	0.05	9.16	1887	10.49
1887-88	0	0	0.25	0	1.35	1.81	3.95	1.09	3.29	0.23	0.81	0	12.78	1888	14.54
1889-89	0	0	0.65	0	1.76	2.76	0.81	0.94	3.58	1.15	1.22	0	12.87	1889	25.14
1889-90	0	0	0	4.28	1.62	11.54	7.67	2.67	0.83	0.34	0.37	0	29.32	1890	15.96
1890-91	0	0	0.10	0	1.32	2.66	1.06	3.68	0.95	2.36	0.09	0.08	12.30	1891	13.26
1891-92	0	0	0.11	0.02	0.19	4.72	0.66	1.50	3.05	0.82	0.83	0	11.90	1892	17.01
1892-93	0	0	1.25	0	5.86	3.04	1.73	3.34	5.78	1.41	0.46	0	22.87	1893	14.76
1893-94	0	0	0.12	0.05	0	1.87	3.25	2.05	0.82	0.60	1.86	0	10.62	1894	*16.49

RAINFALL AT MONTEREY—(Continued)

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1894-95	0	0	*0.08	1.64	0.32	5.87	6.30	2.55*	1.94	0.89	0.58	0	*20.17	1895	*15.32
1895-96	0	0	0	0.78	0.82	1.46	3.24	0.12	2.20	2.17	0.42	0	11.21	1896	14.21
1896-97	0	0.50	0.27	0.65	2.13	2.51	1.10	3.63	3.70	0.40	0.08	0.32	15.29	1897	11.70
1897-98	0	0	0.12	0.70	0.40	1.25	0.89	1.08	1.27	0.24	0.94	0.06	6.95	1898	7.24
1898-99	0	0	0.79	0.20	0.79	0.98	2.79	0.66	3.07	0.50	0.50	0.05	10.33	1899	15.05
1899-00	0	0.09	0	3.69	2.31	1.39	1.34	0.66	1.18	1.55	0.26	0	12.47	1900	11.77
1900-01	0	0	0	1.03	4.65	1.10	2.48	4.11	1.28	0.96	0.39	0	16.00	1901	12.93
1901-02	0	0	0.62	0.98	1.58	0.53	1.81	3.87	4.22	1.10	0.03	0.24	14.98	1902	14.60
1902-03	0	0	0	0.50	1.66	1.17	3.43	1.88	5.98	0.80	0	0	15.42	1903	14.67
1903-04	0	0	0	0	2.17	0.41	1.17	2.77	3.96	2.27	0	0	12.75	1904	18.34
1904-05	0	0	2.75	1.92	0.44	3.06	3.39	4.46	4.63	1.50	3.10	0	25.25	1905	21.63
1905-06	0	0	0	0	3.53	1.02	4.96	3.12	5.93	0.70	0.93	0	20.19	1906	25.03
1906-07	0	0	0	0	1.59	7.80	7.01	2.24	10.64	0	0.22	0.30	29.80	1907	28.98
1907-08	0	0	0.34	3.32	0	4.91	4.56	2.78	1.06	0.25	0.56	0	17.78	1908	12.21
1908-09	0	0	0	0.66	1.37	0.97	11.69	4.45	4.29	0	0	0	23.43	1909	28.39
1909-10	0	0	0.64	0.29	1.61	5.42	5.14	1.08	3.13	0.47	0	0	17.78	1910	12.35
1910-11	0	0	0.14	0.94	0.90	0.55	9.21	5.73	5.90	0.57	0.45	0	24.39	1911	25.34
1911-12	0	0	0	0.39	0.75	2.34	2.10	0.20	3.13	3.41	0.84	0.12	13.28	1912	....
										Average............			15.97		16.57

*Interpolated data.
(Government Record.)

RAINFALL AT NEWMAN—ELEVATION 91 FEET.

Stanislaus County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1889	....	....	....	....	....	....	0.51	0.64	3.67	0.25	0.99	0	.....	1889	20.13
1889-90	0	0	0	4.28	4.27	5.52	4.56	3.34	0.80	0.70	0.20	0	23.67	1890	12.08
1890-91	0	0	1.31	0	0	1.17	0.28	3.27	1.82	1.55	0.10	0.18	9.68	1891	11.43
1891-92	0	0	0.49	0.05	0	3.69	0.27	1.45	1.77	0.55	0.81	0	9.08	1892	10.83
1892-93	0	0	0	0.28	1.46	4.24	1.03	2.87	4.73	1.67	0	0	16.28	1893	11.16
1893-94	0	0	0	0	0.39	0.47	1.97	0.89	0	T.	0.83	0.33	4.88	1894	10.45
1894-95	0	0	0.80	0.35	0	5.28	3.34	0.87	1.77	0.80	0.90	0	14.11	1895	8.66
1895-96	0	0	0.10	0	0.48	0.40	5.59	0	1.32	1.91	0.43	0	10.23	1896	13.54
1896-97	0.10	0	0	1.35	1.97	0.87	1.83	2.61	1.85	0.47	0.02	0.20	11.27	1897	9.78
1897-98	0	0.10	T.	1.37	0.33	1.00	0.45	0.84	0.80	0.03	0.75	0	5.67	1898	3.48
1898-99	0	0	0.07	0.13	T.	0.41	2.19	0	2.05	0.30	1.05	0.07	6.27	1899	10.97
1899-00	0	0	0	1.65	2.41	1.25	1.94	0.10	0.45	1.91	1.87	T.	11.58	1900	12.20
1900-01	0	0	0.32	0.35	4.45	0.81	1.71	2.94	0.16	0.63	0.71	0	12.08	1901	8.47
1901-02	T.	0	T.	0.58	1.48	0.26	0.62	3.62	0.81	0.65	0.25	0	8.27	1902	8.58
1902-03	T.	0	0	0.61	1.53	0.49	1.47	0.78	4.31	0.07	T.	0	9.26	1903	7.99
1903-04	0	T.	0	T.	1.06	0.30	0.23	1.51	2.33	1.51	0.06	0.04	7.04	1904	9.78
1904-05	0	0.43	1.13	0.92	0.67	0.95	3.00	2.85	2.65	0.55	1.70	0	14.85	1905	12.49
1905-06	0	0	T.	0	0.76	0.98	1.88	1.74	7.27	1.18	0.88	0.04	14.73	1906	19.89
1906-07	0	0	0.04	T.	0.95	5.91	3.35	1.49	3.82	0.03	T.	0.40	15.99	1907	12.14
1907-08	T.	0	T.	1.01	0	2.04	2.91	0.92	0.45	0.03	0.32	0	7.68	1908	6.26
1908-09	0	0	T.	0	0.67	0.96	4.91	3.23	1.71	0	0	0.02	11.50	1909	14.65
1909-10	0	0	0	0.40	0.69	3.69	1.99	0.28	2.60	0.18	0	0	9.83	1910	6.39
1910-11	0	0	0.52	0.12	0.19	0.51	5.70	0.84	3.11	0.27	0.10	T.	11.36	1911	10.56
1911-12	0	0	0	T.	0.10	0.44	1.95	0.01	2.14	0.99	0.98	0.11	6.72	1912	.....
										Average.................			10.96		10.95

(Government Record.)

RAINFALL AT NILES—ELEVATION 77 FEET.
Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1886	....	....	....	....	....	....	5.63	0.73	1.67	4.19	0.25	0.01	.....	1886	15.55
1886-87	T.	0	0	0.64	1.29	1.14	1.07	7.62	1.01	1.87	0.14	0.07	14.85	1887	16.53
1887-88	0.01	0	0.65	T.	0.84	3.25	3.99	1.80	3.07	0.15	0.78	0.40	14.94	1888	17.05
1888-89	0	T.	0.39	0.07	3.87	2.53	0.55	0.42	5.59	0.95	1.59	0.01	15.97	1889	28.98
1889-90	0	0	0	4.30	3.44	12.13	7.18	3.63	3.03	1.12	1.08	0	35.91	1890	19.54
1890-91	0	0	0.45	0	0	3.05	0.65	4.72	2.57	2.23	1.10	0.06	14.83	1891	18.42
1891-92	0	0	0.21	0.06	0.37	6.45	1.12	1.41	3.71	1.10	1.96	T.	16.39	1892	19.64
1892-93	0.03	0	0.01	1.53	3.49	5.28	2.65	2.73	5.58	1.67	0.47	0.02	23.46	1893	18.62
1893-94	0	0	0.14	0.23	2.44	2.69	7.28	4.99	1.23	0.54	1.94	0.43	21.91	1894	29.61
1894-95	0	0	1.42	1.49	0.84	9.45	6.81	2.55	2.15	1.73	0.86	0	27.30	1895	18.73
1895-96	T.	0	0.75	0.72	1.80	1.36	7.45	0.30	1.66	4.47	1.07	0	19.58	1896	26.74
1896-97	0.10	0.83	0.57	1.22	6.16	2.91	2.08	4.47	4.78	0.45	0.16	0.29	24.02	1897	17.52
1897-98	0	0	0	2.42	0.92	1.95	1.71	2.20	0.88	0.39	1.28	0.24	11.99	1898	11.82
1898-99	0	0	1.46	1.33	0.68	1.65	2.78	0.49	6.09	0.26	0.66	0.49	15.89	1899	21.31
1899-00	T.	0.09	0	4.24	3.30	2.91	3.49	0.87	1.87	0.91	0.79	0.08	18.55	1900	16.37
1900-01	T.	0	0.02	2.02	4.67	1.65	....	....	....	....	....	....	.....	1901	.....
(U. S. Weather Bureau.)															
1901-02	....	....	....	....	....	....	....	....	....	....	....	....	.....	1902	.....
1902-03	....	....	....	....	....	....	....	....	....	....	....	....	.....	1903	.....
1903-04	....	....	....	....	....	....	1.33	5.56	4.70	2.11	0.32	0.08	.....	1904	23.21
1904-05	0	0.48	2.80	2.25	1.45	2.13	3.43	3.21	3.51	1.40	2.81	0	23.47	1905	18.90
1905-06	0	0	0.02	0	2.36	2.16	5.27	4.48	5.33	1.33	1.34	0.54	22.83	1906	25.49
1906-07	0	0	0	0	1.81	5.39	4.10	2.99	10.91	0.70	0.40	0.89	27.19	1907	25.83
1907-08	0	0	0	1.40	0.03	4.41	2.97	2.57	0.80	0.23	0.48	0	12.89	1908	10.74
1908-09	0	0	0.15	0.70	1.18	1.66	9.00	7.06	3.19	0	0	0	22.94	1909	27.86
1909-10	0	0	0.66	1.08	1.86	5.01	3.45	1.36	2.55	0.47	0	0	16.44	1910	8.88
1910-11	0	0	0	0	0.14	0.91	13.31	0	4.93	0.85	0.44	0	20.58	1911	22.63
1911-12	0	0	0	1.11	0.38	1.61	2.15	0.20	2.76	1.84	0.71	0.76	11.52	1912	.....
(S. P. Ry. Co.)										Average..................			19.70		20.00

RAINFALL AT OAKDALE—ELEVATION 156.

Stanislaus County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1880-81	....	....	....	0	0.40	6.04	2.40	2.78	1.30	0.18	0	0	.....	1881	9.27
1881-82	0	0	0	0.44	0.55	1.62	2.10	2.35	3.05	2.55	0.13	0	12.79	1882	15.82
1882-83	0	0	0	2.23	1.90	1.51	2.70	0.78	2.90	0.80	2.10	0	14.92	1883	12.10
1883-84	0	0	0	1.25	0.70	0.87	1.70	3.90	4.75	4.90	0.50	....	....	1884	....
1884-85	....	....	....	....	....	....	....	....	....	....	....	....	....	1885	....
1885-86	....	....	....	....	....	....	....	....	....	....	....	....	....	1886	....
1886-87	....	....	....	0.19	0.95	0.79	0.48	3.14	0.17	2.04	0	0	....	1887	8.01
1887-88	0	0	0	0	0.21	1.97	2.56	0.47	2.11	0.27	0.45	0	8.04	1888	11.21
1888-89	0	0	0	0	3.87	1.48	0.37	0.37	2.89	0.27	1.58	....	....	1889	....
1889-90	....	....	....	....	....	....	....	....	....	....	....	....	....	1890	....
1890-91	....	....	....	....	....	....	....	....	....	....	....	....	....	1891	....
1891-92	....	....	....	....	....	....	....	....	....	....	....	....	....	1892	....
1892-93	0	0	0.21	0.78	4.35	2.85	1.88	2.36	5.29	0.78	0.21	0	18.60	1893	13.85
1893-94	T.	0	0.28	0	1.45	1.60	5.46	5.20	0.50	0.88	2.38	1.05	18.80	1894	25.42
1894-95	0	0	0.36	1.23	0.65	7.71	5.72	2.24	2.01	1.62	0.51	0	22.05	1895	14.86
1895-96	0	0	0.20	0.29	1.03	1.24	5.28	0	1.44	3.84	0.58	0	13.90	1896	17.45
1896-97	0	0.10	0	1.61	3.07	1.53	2.58	3.46	2.72	0.65	0.06	0.12	15.90	1897	13.19
1897-98	0	0.04	0.24	1.53	0.54	1.25	0.68	1.01	0.25	0.15	1.52	0	7.21	1898	6.49
1898-99	0	0	0	0.76	0.49	1.63	2.28	0.11	4.64	0.04	0	1.56	11.51	1899	16.47
1899-00	0	0.04	0	2.77	3.21	1.82	1.49	0.18	2.14	2.80	1.60	0	16.05	1900	15.85
1900-01	0	0	0	0.95	5.61	1.08	1.68	5.07	0.38	1.14	0.89	0	16.80	1901	14.41
1901-02	0	0	0.63	1.04	2.57	1.01	0.75	4.72	1.14	0.91	0.58	0	13.35	1902	12.45
1902-03	0	0	0	1.30	2.37	0.68	3.27	0.92	5.53	1.42	0	0	15.49	1903	14.61
1903-04	0	T.	0	0	3.11	0.36	0.70	5.00	3.44	1.74	0.15	0	14.50	1904	16.97
1904-05	0	0.06	1.68	1.43	1.18	1.59	3.54	1.26	2.43	1.04	2.31	0	16.52	1905	12.34
1905-06	0	T.	0	0	0.99	0.77	4.50	3.29	6.81	2.18	1.98	0.20	20.72	1906	28.24
1906-07	0	0	0.05	T.	0.76	8.47	3.72	2.36	6.37	0.19	0.10	0.60	22.62	1907	16.08
1907-08	0	0	0	0.47	T.	2.27	3.17	1.28	0.69	0.07	0.46	0	8.41	1908	8.42
1908-09	T.	0	0.21	0.20	1.15	1.19	5.77	3.21	1.96	0	0	0.06	13.75	1909	16.74
1909-10	0	0	0	0.55	1.83	3.36	2.95	0.83	3.28	0.34	0.06	0	13.20	1910	8.97
1910-11	0	0	0.29	0.16	0.39	0.67	8.63	1.46	4.85	0.88	0.35	0	17.68	1911	17.55
1911-12	0	0	0	0.27	0.11	1.00	2.23	0	2.58	1.12	0.48	0.31	8.10	1912	....
											Average............		14.82		14.45

(Government Record.)

RAINFALL AT OAKLAND—ELEVATION 36 FEET.

Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1874	....	....	....	....	....	....	5.60	1.80	5.25	1.25	0.75	0	.....	1874	26.38
1874-75	0	0	0	2.24	9.18	0.31	6.15	0.30	1.65	0	0.10	1.64	21.57	1875	22.08
1875-76	0	0	0	0.30	7.84	4.10	5.28	4.87	4.55	0.93	0.45	0.24	28.56	1876	21.56
1876-77	0.10	0	0.15	4.74	0.25	0	4.19	1.42	0.96	0.22	0.30	0	12.33	1877	11.09
1877-78	0.18	0	0	0.45	1.62	1.75	10.82	11.63	4.30	1.18	0.40	T.	32.33	1878	31.14
1878-79	0	0	0	1.85	0.65	0.31	4.34	5.65	7.96	1.17	1.39	0.15	23.47	1879	29.40
1879-80	0	0	0	0.70	2.98	5.06	1.71	2.19	1.70	8.46	1.04	0	23.84	1880	28.59
1880-81	0	0	0.57	0	0.35	12.57	10.48	3.95	0.88	1.40	0.40	1.16	31.76	1881	26.07
1881-82	0	0	0.40	0.82	1.49	5.09	2.42	2.05	4.20	1.51	0.15	T.	18.13	1882	18.87
1882-83	0	0	0.42	2.65	4.33	1.14	1.95	0.70	3.33	2.20	3.50	0	17.22	1883	12.76
1883-84	0	0	1.00	1.03	0.90	1.15	3.81	5.25	8.59	5.79	0.55	3.03	31.10	1884	38.20
1884-85	T.	0.25	0.35	2.80	0.05	7.73	1.92	0.48	1.07	3.12	0.10	0.08	17.95	1885	22.58
1885-86	0.02	0	0.05	0.30	11.11	4.33	8.12	0.30	2.57	5.11	0.30	0	32.21	1886	22.34
1886-87	0.15	0	0.05	1.59	0.45	3.60	1.57	7.83	0.71	2.35	0.10	0.05	18.55	1887	16.89
1887-88	0.01	0	0.27	0	0.78	3.22	6.42	1.02	4.44	0.10	0.38	0.46	17.10	1888	22.14
1888-89	0	0	0.92	0.06	3.52	4.82	0.90	0.63	7.60	0.93	1.92	0.07	21.37	1889	35.62
1889-90	0	0	0	7.30	2.89	13.38	10.22	5.72	3.52	1.51	1.17	T.	45.71	1890	26.15
1890-91	T.	T.	0.10	0	0	3.91	0.95	11.37	3.10	2.77	1.60	0.11	23.91	1891	28.31
1891-92	0.15	0	0.87	0.20	0.55	6.64	2.31	3.68	2.89	1.09	2.49	0	20.87	1892	26.52
1892-93	T.	T.	0.04	2.51	5.04	6.47	3.68	3.25	5.76	0.98	0.34	0	28.07	1893	22.66
1893-94	0	0	0.03	0.29	5.76	2.57	9.02	3.70	0.79	0.41	1.89	0.95	25.41	1894	34.19
1894-95	0.01	0	1.66	2.64	1.34	11.78	11.32	3.09	2.00	1.93	1.12	0	36.89	1895	24.52
1895-96	0.03	0	1.07	0.13	2.09	1.74	11.03	0.24	2.64	6.88	0.80	0	26.65	1896	35.21
1896-97	0	0.68	0.82	1.72	6.11	4.29	3.32	5.99	6.00	0.52	0.29	0.42	30.16	1897	23.64
1897-98	T.	T.	0.16	3.27	1.18	2.49	1.30	2.85	0.25	0.19	1.50	0.39	13.58	1898	11.20
1898-99	0	T.	1.16	1.48	0.60	1.48	5.59	0.07	12.16	0.78	1.64	0.06	25.02	1899	34.04
1899-00	0	0	0	4.89	5.65	3.20	4.81	0.87	2.76	1.48	1.07	0.08	24.81	1900	19.31
1900-01	0	T.	0.06	1.60	5.00	1.58	6.44	6.02	0.81	2.62	0.89	0	25.02	1901	22.48
1901-02	0	T.	1.01	0.64	3.15	0.90	2.37	9.73	3.51	1.48	1.13	0	23.92	1902	25.71
1902-03	0	T.	0	1.98	2.37	3.14	4.02	1.68	7.42	0.55	T.	T.	21.16	1903	20.80
1903-04	0	0	0	0.31	5.22	1.60	1.31	9.45	9.56	1.18	0.36	T.	28.89	1904	33.06
1904-05	T.	0.03	4.50	3.29	1.86	1.52	4.91	3.90	3.56	1.34	2.70	0	27.61	1905	19.79
1905-06	0	0	T.	0	1.48	1.90	4.59	3.95	7.90	0.95	2.06	0.55	23.38	1906	27.11
1906-07	0	0	0.21	0	1.22	5.68	4.26	4.04	9.08	0.18	0	1.30	25.97	1907	24.24
1907-08	0	0	0.04	1.62	0.08	3.64	4.09	4.23	1.16	0.31	0.58	0	15.75	1908	14.63
1908-09	0	0	0.13	0.68	1.48	1.97	10.62	7.77	3.13	0	0	0	25.78	1909	32.51
1909-10	T.	0	0.69	1.42	2.66	6.22	3.16	1.64	3.66	0.27	0.02	0.01	19.75	1910	12.02
1910-11	T.	0	0.06	0.55	0.65	2.00	15.35	2.56	5.08	1.21	0.19	0.11	27.76	1911	27.52
1911-12	0	T.	0.01	0.38	0.35	2.28	2.31	0.49	2.68	1.07	1.33	0.68	11.58	1912	.....
(Government Record.)										Average			24.35		24.51

RAINFALL AT PESCADERO—ELEVATION 420 FEET.

San Mateo County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1889-90	....	....	....	....	....	....	....	....	....	....	....	....	93.67	1890	....
1890-91	....	....	....	....	....	....	....	....	....	....	....	....	46.71	1891	....
1891-92	....	....	....	....	....	....	....	....	....	....	....	....	40.76	1892	....
1892-93	....	....	....	....	....	....	....	....	....	....	....	....	72.83	1893	....
1893-94	....	....	....	....	....	....	....	....	....	....	....	....	49.91	1894	....
1894-95	....	....	....	....	....	29.21	21.24	5.54	5.07	0.94	0.09	0	68.49	1895	....
1895-96	0.03	0	0.40	1.14	....	....	26.77	1.10	4.22	11.46	1.95	0	54.72	1896	....
1896-97	0.10	1.35	0.45	2.79	1.50	6.13	....	....	12.79	0.14	0.25	1.28	63.13	1897	....
1897-98	....	....	....	1.35	1.71	....	3.09	8.38	1.58	0.73	3.68	0.66	24.35	1898	23.98
	(Journals.)														
1898-99	0	0	1.72	1.14	0.93	2.07	12.86	1.04	18.92	1.10	2.45	0.31	42.54	1899	63.00
1899-00	0	0	0.15	10.29	7.78	8.10	9.61	1.86	5.40	3.53	1.01	0	47.73	1900	43.08
1900-01	0	0	0.29	5.03	12.62	3.73	7.56	12.45	1.95	6.53	2.19	0	52.35	1901	41.51
1901-02	0	0	1.83	2.04	4.72	2.24	2.62	20.15	9.21	4.34	1.73	0	48.88	1902	52.76
1902-03	0	0	0	3.57	6.43	4.71	11.69	4.68	16.21	0.88	0	0	48.17	1903	49.27
1903-04	0	0	0	1.38	12.79	1.64	2.46	17.62	15.42	4.56	0.34	0	56.21	1904	63.42
1904-05	0	0.40	5.52	7.80	3.44	5.86	7.19	8.56	10.67	1.74	5.47	0	56.65	1905	42.56
1905-06	0	0	0	0	5.18	3.75	20.05	7.25	16.55	1.95	5.65	0	60.38	1906	....
1906-07	....	....	....	....	....	....	....	....	....	....	....	....	....	1907	....
1907-08	....	....	....	....	....	....	....	....	....	....	....	....	....	1908	....
1908-09	....	....	....	....	....	....	....	....	....	....	....	....	....	1909	....
1909-10	....	....	....	....	....	....	....	....	....	....	....	....	....	1910	....
1910-11	....	....	....	....	....	....	....	....	....	....	....	....	....	1911	....
1911-12	....	....	....	....	....	....	....	....	....	....	....	....	....	1912	....
	(Creek Gaging.)								Average..........		927.48 / 17	=	54.55		47.47

Records S. V. W. Co.

RAINFALL AT PILARCITOS—ELEVATION 695 FEET.

San Mateo County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1864-65	0	0	0	0	13.81	23.09	5.71	6.12	3.12	1.23	1.87	0	54.95	1865	34.19
1865-66	0	0	0.24	1.29	10.90	3.71	24.46	6.30	9.18	0.45	2.91	0	59.44	1866	77.88
1866-67	0	0	0	0	7.81	26.77	11.63	15.57	3.30	2.38	3.71	0	71.17	1867	68.73
1867-68	0	0	0.65	1.61	8.02	21.86	18.22	8.45	16.79	4.67	0.43	1.01	81.71	1868	59.89
1868-69	0	0	0	0.25	2.59	7.48	15.18	7.49	7.06	6.21	2.00	0	48.26	1869	56.33
1869-70	0	0	0	4.92	3.98	9.49	12.47	9.78	4.60	3.31	1.11	0	49.66	1870	41.07
1870-71	0	0	0.39	0.37	3.06	5.98	8.39	8.86	6.44	3.82	2.20	0	39.51	1871	73.79
1871-72	0	0	0	0.20	5.93	37.95	10.14	15.38	3.97	3.46	0.09	0.33	78.45	1872	58.54
1872-73	0	0	0.12	0.30	4.48	19.27	3.91	9.51	2.54	1.59	0.29	0	42.01	1873	36.71
1873-74	0.18	0	0	1.82	1.85	15.02	12.20	5.24	8.37	2.84	1.88	0.91	50.31	1874	52.23
1874-75	0	0	0	4.10	16.00	0.69	15.04	1.03	5.24	0.11	0.94	1.18	44.33	1875	49.58
1875-76	0	0	0	0.65	16.93	8.46	14.57	10.33	12.04	1.94	1.53	0.07	66.52	1876	48.80
1876-77	0	0.07	0.86	6.85	0.54	0	5.28	2.08	4.81	0.85	1.45	0	22.79	1877	24.93
1877-78	0.28	0	0	1.34	3.83	5.01	21.43	25.28	11.60	2.87	0.46	0	72.10	1878	69.25
1878-79	0	0	1.57	2.37	1.61	2.06	9.69	13.31	19.71	4.67	3.13	0	58.12	1879	71.53
1879-80	0	0	0.13	2.44	6.74	11.71	6.50	4.09	3.95	20.06	3.78	0	59.40	1880	68.24
1880-81	0	0	0	0.18	0.65	29.03	17.00	8.82	2.25	2.53	0.38	1.67	62.51	1881	50.25
1881-82	0	0	0.92	2.71	2.88	11.09	5.94	5.39	7.66	4.77	0.55	0	41.91	1882	41.24
1882-83	0	0	0.17	5.97	7.57	3.22	5.08	1.26	7.02	2.85	6.01	0.11	39.26	1883	32.82
1883-84	0	0	1.70	3.12	2.81	2.86	7.09	10.48	18.08	10.26	0.69	4.50	61.59	1884	79.36
1884-85	0.04	0	0.57	3.77	0.56	23.32	4.95	1.27	1.49	4.93	0.19	0.73	41.82	1885	40.51
1885-86	0.06	0	0.24	0.39	18.12	8.14	13.84	0.92	4.63	11.97	0.82	0.08	59.21	1886	41.54
1886-87	0	0	0	2.28	1.53	5.47	5.88	17.83	2.56	5.33	0.52	0.15	41.55	1887	43.41
1887-88	0	0	0.66	0	2.50	7.98	18.24	4.15	8.31	0.59	1.39	1.47	45.29	1888	54.05
1888-89	0	0	1.37	0.19	7.05	11.29	2.67	2.21	14.76	2.53	4.97	0	47.04	1889	65.84
1889-90	0	0	0	12.11	5.78	20.81	14.19	7.52	6.42	2.75	2.42	0.09	72.09	1890	39.95
1890-91	0	0	0.23	0.07	0.06	6.20	1.73	18.65	5.44	4.14	1.89	0.61	39.02	1891	55.87
1891-92	0.82	0	1.58	0.88	1.54	18.59	4.55	7.46	7.67	3.89	5.70	0.08	52.76	1892	58.56
1892-93	0.28	0	0.22	2.85	9.80	16.06	6.85	8.17	17.35	4.44	0.88	0.10	67.00	1893	62.00
1893-94	0	0	1.64	1.65	14.60	6.32	18.09	14.50	3.97	1.97	4.50	0.57	67.81	1894	79.36
1894-95	0	0	2.45	6.77	2.43	24.11	21.19	7.26	6.36	2.89	2.64	0	76.10	1895	53.34
1895-96	0.45	0	2.86	0.65	3.20	5.84	21.45	0.88	5.06	11.02	4.26	0.47	56.14	1896	69.49
1896-97	0.10	0.27	0.50	1.96	12.84	10.68	4.09	14.12	11.10	1.35	0.87	0.69	58.57	1897	45.49
1897-98	0	0	0	4.88	3.10	5.29	3.42	6.55	1.53	0.79	4.20	1.40	31.16	1898	27.00
1898-99	0	0	1.99	2.08	2.60	2.44	9.81	0.47	26.90	1.40	0.99	2.80	51.48	1899	68.04
1899-00	0	0.27	0	8.28	10.44	6.68	11.18	2.94	7.98	4.14	0.79	0.05	52.75	1900	47.27
1900-01	0	0.02	0.57	6.02	9.01	4.57	8.81	12.02	2.97	5.50	2.79	0	52.28	1901	46.18
1901-02	0.05	0	2.16	1.87	6.15	3.86	3.67	20.01	6.10	3.10	1.36	0.21	48.54	1902	47.48
(P. 86.)															
1902-03	0	0	0	3.09	5.06	4.88	10.94	3.32	10.20	1.98	0	0	39.47	1903	41.37
1903-04	0	0	0	1.16	11.52	2.25	3.20	15.39	18.78	3.70	0.70	0.16	56.86	1904	65.43
1904-05	0.14	0.07	8.27	7.36	3.56	4.10	5.51	6.07	7.30	2.20	3.42	0	48.00	1905	31.86
1905-06	0	0	0	0	3.14	4.22	9.58	7.84	11.04	1.49	3.19	0.83	41.33	1906	44.16
1906-07	0	0	0.22	0.03	1.36	8.58	8.12	7.32	15.57	1.02	0.66	0.99	43.87	1907	42.48
1907-08	0	0	0.39	2.41	0.10	5.90	7.41	8.73	1.92	0.99	2.06	0.30	30.21	1908	30.76
1908-09	0	0.02	0.24	2.40	2.93	3.67	24.92	12.94	5.67	0	0.06	0.10	53.04	1909	61.94
1909-10	0	0	1.98	2.69	5.02	8.56	5.82	4.82	5.24	0.79	0	0.07	34.99	1910	22.86
1910-11	0	0	0.03	1.26	1.81	3.02	23.94	6.44	6.57	3.75	0.79	0.06	47.67	1911	49.07
1911-12	0	0	0	1.24	1.88	4.40	6.28	1.04	3.98	3.04	2.69	1.05	25.60	1912	.....
										Average			51.78		51.71

Records S. V. W. Co.

RAINFALL AT PORTOLA—ELEVATION 370 FEET.

San Mateo County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1892-93	0	0	0	1.82	5.45	7.95	3.77	3.56	7.51	2.16	0.18	0	32.40	1893	23.20
1893-94	0	0	0.42	0.12	3.02	2.46	8.57	9.12	1.22	1.17	1.25	0.08	27.43	1894	38.86
1894-95	0	0	1.76	2.91	0.58	12.20	12.89	3.58	2.39	1.76	0.93	0	39.00	1895	26.20
1895-96	0	0	0.18	0.35	1.59	2.53	12.21	0.21	2.59	7.53	0.87	0	28.06	1896	40.83
1896-97	0	1.39	0.35	1.29	9.62	4.77	2.40	6.24	8.27	0.28	0	0	34.61	1897	23.67
1897-98	0	0	0	2.46	0.85	3.17	1.82	3.77	0.77	0.25	1.36	0.25	14.70	1898	13.24
1898-99	0	0	1.84	1.13	0.55	1.50	5.33	0.47	15.51	0.50	0.26	1.40	28.49	1899	38.37
1899-00	0	0	0	5.70	5.19	4.01	5.69	0.90	4.03	1.97	0.55	0	28.04	1900	27.48
1900-01	0	0	0.06	4.47	7.17	2.64	4.92	7.57	1.70	2.57	1.70	0	32.80	1901	25.07
1901-02	0	0	0.96	1.17	2.74	1.74	2.58	10.83	6.37	3.15	1.15	0.19	30.88	1902	32.84
1902-03	0	0	0	2.61	4.04	1.92	7.64	2.68	9.45	1.46	0	0	29.80	1903	29.23
1903-04	0	0	0	0.68	6.06	1.26	2.01	11.82	11.22	2.43	0.51	0	35.99	1904	40.26
(Letter File 3.)															
1904-05	0	0.20	2.84	4.32	1.42	3.49	4.18	4.39	6.05	1.79	3.44	0	32.12	1905	27.33
1905-06	0	0	0	0	4.00	3.48	14.93	5.61	9.36	1.25	2.27	0.53	41.43	1906	.....
1906-07										Average.................			31.12		29.74
1907-08															
(J. R. & W. B. Lawrence Notes.)															
1908-09	....	....	....	....	....	0.61	22.97	9.27	6.20	0	[illegible]	0	44.10	....	.....
1909-10															
Records S. V. W. Co.															

RAINFALL AT SAN ANDREAS—ELEVATION 445 FEET.

San Mateo County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1868	....	....	....	....	....	....	....	....	....	4.26	0.22	0.85	....	1868	....
1868-69	0	0	0	0.20	1.20	5.57	12.30	9.61	3.92	4.75	1.03	0	38.58	1869	47.34
1869-70	0	0	0	4.14	1.75	9.84	7.60	7.91	2.73	2.26	0.38	0	36.61	1870	28.24
1870-71	0	0	0.14	0.34	1.83	5.05	6.47	8.19	3.54	3.39	1.72	0	30.67	1871	74.23
1871-72	0	0	0	0.06	4.45	46.41	10.94	13.96	3.58	3.18	0.07	0.07	82.72	1872	52.79
1872-73	0	0	0.09	0.23	2.95	17.72	2.89	8.81	2.07	1.27	0.30	0	36.33	1873	32.75
1873-74	0	0	0	1.16	0.96	15.29	12.01	4.16	8.86	3.03	1.60	0.56	47.63	1874	50.48
1874-75	0	0	0	4.41	15.19	0.66	16.56	0.76	4.45	0.17	0.86	1.34	44.40	1875	52.23
1875-76	0	0	0	0.43	17.30	10.36	12.82	14.08	13.82	2.17	1.45	0	72.43	1876	52.80
1876-77	0	0	0.40	7.73	0.33	0	5.46	1.83	4.02	0.47	1.71	0	21.95	1877	23.21
1877-78	0	0	0	1.17	3.98	4.57	23.11	27.87	10.22	2.45	0.23	0	73.60	1878	69.73
1878-79	0	0	1.30	2.26	1.45	0.84	8.58	12.87	19.82	3.72	3.15	0.09	54.08	1879	67.83
1879-80	0	0	0	1.80	6.06	11.74	5.47	4.03	3.53	17.81	3.16	0	53.60	1880	57.73
1880-81	0	0	0	0.01	0.55	23.17	13.42	4.24	1.46	1.69	0.16	0.58	45.28	1881	31.97
1881-82	0.08	0	0.40	1.45	1.55	6.94	2.72	4.02	6.06	3.15	0.23	0.03	26.63	1882	26.63
1882-83	0	0	0.07	3.62	5.36	1.37	3.51	0.85	6.34	2.70	4.74	0	28.56	1883	24.05
1883-84	0	0	1.15	2.07	0.91	1.78	6.60	9.69	14.24	8.54	0.38	3.03	48.39	1884	65.75
1884-85	0	0.05	0.25	3.11	0.39	19.47	4.20	0.60	0.73	5.12	0.15	0.53	34.60	1885	31.28
1885-86	0.03	0	0.09	0.30	13.81	5.72	10.16	0.93	3.88	9.09	0.67	0	44.68	1886	31.03
1886-87	0	0	0	2.17	1.42	2.71	2.91	14.44	1.74	4.04	0.27	0.07	29.77	1887	32.80
1887-88	0	0	0.47	0	2.06	6.80	11.07	2.71	6.77	0.67	0.94	0.72	32.21	1888	37.37
1888-89	0	0	0.93	0.09	6.11	7.36	2.39	1.56	11.91	1.45	3.50	0	35.30	1889	60.87
1889-90	0	0	0	10.49	5.94	23.63	15.75	7.63	6.83	2.46	2.51	0.01	75.25	1890	40.18
1890-91	0	0	0.10	0	0.02	4.87	1.55	20.57	4.69	3.57	0.97	0.23	36.57	1891	46.06
1891-92	0.18	0	0.94	0.21	0.76	12.39	2.98	4.63	5.66	2.08	3.68	0	33.51	1892	42.22
1892-93	0.24	0	0	2.15	7.13	13.67	5.62	6.37	10.84	3.13	0.45	0	49.60	1893	37.41
1893-94	0	0	0.67	0.83	5.83	3.67	13.78	10.26	2.60	1.71	2.28	0.29	41.92	1894	57.91
1894-95	0	0	2.02	5.22	1.32	18.43	18.55	4.27	4.34	2.41	1.21	0	57.77	1895	38.87
1895-96	0.08	0	1.29	0.46	2.32	3.94	21.45	0.72	3.62	8.78	2.07	0.02	44.75	1896	57.72
1896-97	0	0.29	0.50	1.90	10.05	8.32	3.44	9.66	7.25	0.69	0.06	0.22	42.38	1897	29.90
1897-98	0	0	0	3.26	1.78	3.54	1.92	5.31	1.13	0.63	3.04	0.75	21.36	1898	18.56
1898-99	0	0	1.70	1.16	1.76	1.76	6.80	0.73	16.39	1.31	0.72	1.91	33.64	1899	46.42
1899-00	0	0.15	0	5.98	7.43	5.00	8.34	2.14	4.20	2.86	0.55	0.03	36.68	1900	31.83
1900-01	0	0	0.37	3.37	6.80	3.17	6.29	8.79	1.68	3.07	1.89	0.03	35.46	1901	30.16
1901-02	0	0	1.38	1.24	3.48	2.31	2.43	12.54	5.90	2.22	1.18	0.15	32.83	1902	36.19
1902-03	0	0	0	3.68	4.43	3.66	9.56	3.84	9.46	1.88	0.02	0	36.53	1903	37.07
1903-04	0	0	0	0.97	9.57	1.77	2.12	10.99	12.04	2.72	0.38	0	40.56	1904	44.84
1904-05	0.05	0.04	6.81	4.61	1.97	3.11	5.69	6.33	6.99	2.43	3.56	0	41.59	1905	31.71
1905-06	0	0	0	0	2.98	3.73	9.00	5.19	9.52	1.03	2.62	0.24	34.31	1906	38.14
1906-07	0	0	0.18	0.05	2.67	7.64	7.61	5.06	17.63	0.84	0.42	0.98	43.08	1907	41.53
1907-08	0	0	0.25	2.39	0.16	6.19	5.05	7.96	2.20	0.46	1.16	0.11	25.93	1908	24.71
1908-09	0	0	0.27	1.36	2.87	3.27	25.98	12.34	5.49	0	0.08	0.05	51.71	1909	57.79
(P. 86.)															
1909-10	0	0	1.10	1.55	2.54	8.66	7.14	3.56	5.17	1.08	0	0.02	30.82	1910	21.76
1910-11	0	0	0.02	0.83	1.25	2.69	25.20	6.16	7.26	3.62	0.77	0.10	47.90	1911	49.48
1911-12	0	0	0	0.56	1.94	3.87	4.90	0.42	4.35	2.33	2.37	1.06	21.80	1912	....
(C. D. D.)															
Records S. V. W. Co.											Average	....	41.68		42.13

RAINFALL AT SAN FRANCISCO.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1849-50	0	0	0	3.14	8.66	6.20	8.31	1.77	4.53	0.46	0	0	33.10	1850	17.40
1850-51	0	0	0.33	0	0.92	1.05	0.72	0.54	1.94	1.23	0.67	0.02	7.42	1851	15.60
1851-52	0	0.02	1.03	0.21	2.12	7.10	0.58	0.14	6.68	0.26	0.32	0	18.46	1852	27.29
1852-53	0	0	0	0.80	5.31	13.20	3.92	1.42	4.86	5.37	0.38	0	35.26	1853	21.17
1853-54	0	0.04	0.46	0.12	2.28	2.32	3.88	8.04	3.51	3.12	0.02	0.08	23.87	1854	22.45
1854-55	0	0.01	0.15	2.43	0.34	0.87	3.67	4.77	4.64	5.00	1.88	0	23.76	1855	26.39
1855-56	0	0	0	0	0.67	5.76	9.40	0.50	1.60	2.94	0.76	0.03	21.66	1856	22.31
1856-57	0.02	0	0.07	0.45	2.79	3.75	2.45	8.59	1.62	0	0.05	0.12	19.91	1857	20.96
1857-58	0	0.05	0	0.93	3.01	4.14	4.36	1.83	5.55	1.55	0.34	0.05	21.81	1858	23.46
1858-59	0.05	0.16	0	2.74	0.69	6.14	1.28	6.32	3.02	0.27	1.55	0	22.22	1859	21.39
1859-60	0	0.02	0.03	0.05	7.28	1.57	1.64	1.60	3.99	3.14	2.86	0.09	22.27	1860	21.18
1860-61	0.21	0	0	0.91	0.58	6.16	2.47	3.72	4.08	0.51	1.00	0.08	19.72	1861	25.52
1861-62	0	0	0.02	0	4.10	9.54	24.36	7.53	2.20	0.73	0.74	0.05	49.27	1862	38.63
1862-63	0	0	0	0.52	0.15	2.35	3.63	3.19	2.06	1.61	0.23	0	13.74	1863	15.10
1863-64	0	0	0.03	0	2.55	1.80	1.83	0	1.52	1.57	0.78	0	10.08	1864	21.64
1864-65	0	0.21	0.01	0.13	6.68	8.91	5.14	1.34	0.74	0.94	0.63	0	24.73	1865	14.06
1865-66	0	0	0.24	0.26	4.19	0.58	10.88	2.12	3.04	0.12	1.46	0.04	22.93	1866	36.28
1866-67	0	0	0.11	0	3.35	15.16	5.16	7.20	1.58	2.36	0	0	34.92	1867	30.64
1867-68	0	0	0.04	0.20	3.41	10.69	9.50	6.13	6.30	2.31	0.03	0.23	38.84	1868	30.17
1868-69	0	0	0	0.15	1.18	4.34	6.35	3.90	3.14	2.19	0.08	0.02	21.35	1869	22.59
1869-70	0	0	0.12	1.29	1.19	4.31	3.89	4.78	2.00	1.53	0.20	0	19.31	1870	16.24
1870-71	0	0	0.03	0	0.43	3.38	3.07	3.76	1.05	1.89	0.23	0.01	14.11	1871	27.53
1871-72	0	0.02	0	0.07	2.81	14.36	4.03	6.90	1.59	0.81	0.18	0.04	30.78	1872	22.42
1872-73	0.01	0	0.04	0.11	2.79	5.95	1.58	3.94	0.78	0.43	0	0.02	15.66	1873	18.56
1873-74	0.01	0.08	0	0.83	1.16	9.72	5.66	2.21	3.36	0.90	0.66	0.14	24.73	1874	22.52
1874-75	0	0	0.02	2.69	6.55	0.33	8.01	0.32	1.30	0.10	0.22	1.02	20.56	1875	22.63
1875-76	0	0	0	0.24	7.27	4.15	7.55	4.92	5.49	1.29	0.24	0.04	31.19	1876	23.54
1876-77	0.01	0.01	0.38	3.36	0.25	0	4.32	1.18	1.08	0.26	0.18	0.01	11.04	1877	11.93
1877-78	0.02	0	0	0.65	1.57	2.66	11.97	12.52	4.56	1.06	0.16	0.01	35.18	1878	33.26
1878-79	0.01	T.	0.55	1.27	0.57	0.58	3.52	4.90	8.75	1.89	2.35	0.05	24.44	1879	30.76
1879-80	0.01	0.02	T.	0.78	4.03	4.46	2.23	1.87	2.08	10.06	1.12	0	26.66	1880	30.07
1880-81	0	0	0	0.05	0.33	12.33	8.69	4.65	0.90	2.00	0.22	0.69	29.86	1881	23.73
1881-82	0	0	0.25	0.54	1.94	3.85	1.68	2.96	3.45	1.22	0.21	0.04	16.14	1882	18.67
1882-83	0	0	0.26	2.66	4.18	2.01	1.92	1.04	3.01	1.51	3.52	0.01	20.12	1883	15.43
1883-84	0	0	0.42	1.48	1.60	0.92	3.94	6.65	8.24	6.33	0.23	2.57	32.38	1884	38.82
1884-85	T.	0.04	0.33	2.55	0.26	7.68	2.53	0.30	1.01	3.17	0.04	0.19	18.10	1885	24.90
1885-86	0.06	T.	0.11	0.72	11.78	4.99	7.42	0.24	2.07	5.28	0.37	0.01	33.05	1886	20.02
1886-87	0.23	T.	0.01	1.48	0.84	2.07	1.90	9.24	0.84	2.30	0.06	0.07	19.04	1887	19.04
1887-88	T.	0.01	0.29	T.	0.99	3.34	6.81	0.94	3.60	0.11	0.38	0.27	16.74	1888	23.03
1888-89	0.01	0.01	0.98	0.13	3.99	5.80	1.28	0.72	7.78	0.96	2.17	0.03	23.86	1889	36.94
1889-90	0.01	T.	T.	7.28	2.90	13.81	9.61	5.16	4.73	1.18	1.07	0.10	45.85	1890	25.43
1890-91	0.02	0	0.31	0	0	3.25	0.98	7.26	1.96	2.44	1.25	0.11	17.58	1891	21.11
1891-92	0.10	0.02	0.77	0.04	0.56	5.62	2.42	2.90	2.85	1.39	1.86	T.	18.53	1892	22.08
1892-93	0	0	0.02	1.65	3.91	5.08	3.05	2.75	4.08	1.03	0.15	0.03	21.75	1893	17.91
1893-94	0.02	0	0.21	0.16	4.18	2.25	5.99	2.69	0.60	0.50	1.31	0.56	18.47	1894	24.32
1894-95	T.	0	1.05	1.73	0.88	9.01	6.99	2.31	1.89	1.24	0.60	0	25.70	1895	17.13
1895-96	0.01	0	0.77	0.11	1.78	1.43	8.14	0.28	2.85	5.16	0.72	0	21.25	1896	28.25
1896-97	0.04	0.09	0.52	1.55	4.56	4.34	2.26	4.41	4.56	0.27	0.61	0.22	23.43	1897	16.40
1897-98	T.	T.	0.10	1.70	1.05	1.22	1.12	2.13	0.24	0.19	1.44	0.19	9.38	1898	9.31

(Records of U. S. Weather Bureau.)

RAINFALL AT SAN FRANCISCO—(Continued).

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1898-99	0	T.	1.06	0.86	0.46	1.62	3.67	0.10	7.61	0.62	0.86	0.01	16.87	1899	23.23
1899-00	0	T.	0	3.92	3.79	2.65	4.11	0.64	1.91	1.08	0.32	0.05	18.47	1900	15.33
1900-01	T.	T.	0.46	1.48	3.91	1.37	5.79	5.03	0.80	1.64	0.69	T.	21.17	1901	19.75
1901-02	T.	T.	0.78	0.64	3.48	0.90	1.23	7.27	2.65	0.98	1.05	T.	18.98	1902	19.18
1902-03	T.	T.	T.	1.70	1.98	2.32	3.73	1.76	6.23	0.56	T.	T.	18.28	1903	18.33
1903-04	0	T.	T.	0.17	4.25	1.63	1.05	5.89	6.01	1.29	0.30	T.	20.59	1904	24.72
1904-05	0.02	0.06	5.07	2.37	1.07	1.59	4.04	2.70	3.15	1.33	2.05	0	23.45	1905	16.24
1905-06	0	T.	T.	T.	0.92	2.05	3.90	4.30	5.02	0.92	2.75	0.56	20.42	1906	26.34
1906-07	0.08	0.11	0.18	0.03	1.59	6.90	4.41	3.02	8.42	0.11	0.04	1.28	26.17	1907	22.47
1907-08	T.	0.02	0.11	1.36	0.04	3.66	4.88	5.39	0.90	0.22	0.76	0.01	17.35	1908	16.42
1908-09	0.02	0.01	0.13	0.61	1.34	2.15	10.51	7.53	3.27	T.	T.	T.	25.57	1909	31.36
1909-10	0	T.	0.80	1.23	2.43	5.59	3.24	2.09	3.78	0.31	0.03	0.02	19.52	1910	12.38
1910-11	T.	0	0.05	0.65	0.48	1.73	13.79	3.02	4.57	0.89	0.28	0.03	25.49	1911	26.00
1911-12	T.	0	T.	0.28	0.60	2.54	2.47	0.41	4.10	1.38	1.47	0.81	14.06	....	.....
											Average	....	22.80		22.71

From records of U. S. Weather Bureau.

RAINFALL AT SAN LEANDRO—ELEVATION 48 FEET.

Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1895	....	....	....	....	....	....	8.21	2.69	2.06	1.96	0.82	0	.....	1895	21.27
1895-96	0.08	0	0.63	0.26	2.31	2.25	9.84	0.25	2.03	5.86	0.91	0	24.42	1896	31.24
1896-97	0.04	1.34	0.89	1.41	5.78	2.89	3.13	5.79	6.03	0.50	0.12	0.22	28.14	1897	22.20
1897-98	0	0	0.10	2.67	1.21	2.43	1.33	2.66	0.39	0.38	1.44	0.36	12.97	1898	11.66
1898-99	0	0	1.13	1.43	0.96	1.58	3.68	0.20	10.85	0.82	1.18	0.21	22.04	1899	28.84
1899-00	0	T.	0	4.38	4.76	2.76	3.93	1.24	2.63	1.88	0.58	0	22.16	1900	19.08
1900-01	0	0	0.04	1.78	5.09	1.91	4.42	5.45	0.91	2.55	0.99	0.02	23.16	1901	19.98
1901 02	0	0.02	0.93	0.60	2.69	1.40	1.65	7.12	3.77	1.39	1.46	0	21.03	1902	23.88
1902-03	0	0	0	2.24	3.00	3.25	4.89	1.94	6.61	0.74	0	0	22.67	1903	21.36
1903-04	0	0	0	0.31	5.78	1.09	1.39	9.46	8.33	2.28	0.23	0.02	28.89	1904	31.36
1904-05	0.07	0.12	2.95	2.88	1.95	1.68	4.34	3.27	4.16	1.63	2.54	0	25.59	1905	*22.22
1905-06	0	*0.12	*0.59	*1.56	1.75	2.26	5.51	4.22	4.16	0.76	1.91	0.60	23.44	1906	26.99
1906-07	0	0	0.12	0.06	1.73	7.92	5.75	5.31	....	....	....	....	.....	1907	.....
1907-08	....	....	....	....	....	....	....	....	....	....	0.74	T.	.....	1908	.....
1908-09	0	0	0.28	0.65	2.01	2.00	13.07	8.24	3.67	0	0	T.	29.92	1909	.....
1909-10	T.	0	0.84	0.74	2.65	....	3.71	1.50	3.10	....	....	....	.....	1910	.....
1910-11	....	....	0.02	0.47	0.54	1.58	16.72	3.55	4.22	1.41	0.41	0.07	.....	1911	.....
1911-12	T.	T.	0.22	....	....	....	....	....	....	....	....	....	.....	1912	.....
										Average	....	....	23.70		23.34

(Government Record.) *Interpolated data.

RAINFALL AT SAN JOSE—ELEVATION 95 FEET.

Santa Clara County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1874	....	....	....	....	....	....	2.61	0.77	2.83	0.87	0.21	0	.....	1874	11.19
1874-75	0	0	0.10	1.81	1.91	0.08	2.75	0.41	0.39	T.	T.	0.45	7.90	1875	12.21
1875-76	0	0	0	T.	6.10	2.12	4.08	3.41	3.11	0.41	0.25	0	19.47	1876	12.55
1876-77	T.	0	0.11	1.17	0.01	0	2.23	0.48	0.78	0	0.05	0	4.83	1877	6.63
1877-78	0	0	0	0.37	0.85	1.87	5.53	6.94	2.22	1.48	0.02	0	19.28	1878	19.20
1878-79	0	0	0.48	0.80	0.76	0.97	1.48	3.18	5.85	1.24	1.58	0.06	16.40	1879	19.04
1879-80	0	0	0	0.87	1.79	2.99	1.48	1.35	0.96	3.66	0.67	0	13.77	1880	14.21
1880-81	0	0	0	0	0.49	5.60	2.12	2.04	0.80	1.28	0	0.12	12.45	1881	9.54
1881-82	0	0	0.02	0.45	0.88	1.83	1.17	1.49	4.26	1.10	0.55	0	11.75	1882	11.62
1882-83	0	0	0.04	0.87	1.32	0.82	1.06	0.94	2.70	0.66	2.18	0	10.59	1883	8.95
1883-84	0	0	0.09	0.67	0.28	0.37	3.18	3.68	6.23	3.38	0.05	2.15	20.08	1884	24.21
1884-85	0	0	0.08	1.50	0.06	3.90	1.83	0.18	0.86	2.75	0.11	T.	11.27	1885	15.29
1885-86	0	0	0	0.06	7.39	2.11	3.59	1.12	1.89	4.47	0	0	20.63	1886	13.03
1886-87	0.03	0	0	0.49	0.73	0.71	0.68	6.81	0.63	1.28	0	0	11.36	1887	13.29
1887-88	0.02	0	0.61	0.03	0.70	2.53	3.06	1.09	3.00	0.31	0.60	0.22	12.17	1888	15.20
1888-89	0	0	0.60	0	3.88	2.44	0.50	0.70	5.80	0.79	0.96	0.04	15.71	1889	25.55
1889-90	0	0	0	4.48	1.73	10.55	6.52	3.64	2.08	0.55	0.75	0	30.30	1890	16.04
1890-91	0	0	0.05	0	0.05	2.40	0.55	5.27	2.46	1.79	0.26	0.05	12.88	1891	17.13
1891-92	0	0	0.37	0.08	0.46	5.84	1.11	1.60	4.75	0.65	1.60	0.05	16.51	1892	22.53
1892-93	0	0	0	1.00	4.00	7.77	2.95	2.68	5.12	1.35	0.30	0	25.17	1893	14.90
1893-94	0	0	0	0	0.81	1.69	4.73	2.61	0.69	0.63	1.36	0.40	12.92	1894	21.17
1894-95	0	0	1.08	1.32	0.55	7.80	6.28	1.42	1.46	2.05	1.36	0	23.32	1895	15.37
1895-96	0	0	0.05	0.83	1.08	0.84	5.17	0.27	2.22	2.79	0.44	0	13.69	1896	18.63
1896-97	0.01	0.74	0.32	1.30	2.82	2.55	1.68	3.43	2.64	0.91	0.16	T.	16.56	1897	11.61
1897-98	0	0	0.21	1.01	0.37	1.20	0.93	1.93	0.52	0.20	0.44	0.06	6.87	1898	6.71
1898-99	0	0	1.13	0.61	0.45	0.44	1.88	0.21	4.17	0.48	0.65	T.	10.02	1899	14.78
1899-00	0	0	0	3.26	2.70	1.43	2.05	0.44	1.36	1.66	0.96	0.01	13.87	1900	12.97
1900-01	0.02	0	0.17	0.62	4.36	1.32	3.98	5.47	0.75	2.37	0.82	T.	19.88	1901	16.32
1901-02	0	T.	0.44	1.00	1.06	0.43	0.81	4.42	2.65	1.29	0.88	0	12.98	1902	14.10
1902-03	0	0	0	0.95	2.18	0.92	2.74	1.27	4.99	0.84	0	0	13.89	1903	11.29
1903-04	0	0	0	0.12	0.99	0.34	1.28	3.01	2.73	1.74	0.26	0	10.47	1904	16.12
1904-05	0	0.25	1.94	1.43	1.20	2.28	2.70	2.65	2.73	1.01	1.77	0	17.96	1905	14.26
1905-06	0	0	T.	0	2.17	1.23	2.86	2.31	4.47	0.90	0.75	0.43	15.12	1906	19.23
1906-07	0	0	0.13	0.01	0.98	6.39	4.61	1.88	7.75	0.46	0.08	0.42	22.71	1907	20.02
1907-08	T.	0	0.06	0.98	0.13	3.65	2.63	2.46	1.14	0.23	0.67	0.01	11.69	1908	9.80
1908-09	0	0	0.09	0.19	1.11	1.54	7.69	4.87	2.77	0	0	0.05	18.31	1909	23.49
1909-10	0	0	0.75	0.72	1.27	5.37	2.31	0.83	2.84	0.41	T.	0.02	14.52	1910	7.66
1910-11	T.	0	0.09	0.20	0.28	0.68	12.38	2.03	6.26	0.45	0.21	0.07	22.65	1911	24.41
1911-12	0	0	0	0.80	0.18	2.03	1.36	0.30	2.80	1.95	0.70	0.46	10.58	1912	.....
										Average	....		15.28		15.27

(Government Record.)

RAINFALL AT SAN MATEO—ELEVATION 22 FEET.

San Mateo County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1874	....	....	....	....	....	....	5.22	1.32	2.16	0.99	0.79	0	.....	1874	16.72
1874-75	0	0	0	2.46	3.71	0.07	4.62	0.56	0.82	0	0	0	12.24	1875	17.00
1875-76	0	0	0	0	7.85	3.15	6.30	4.61	4.16	0.20	0	0	26.27	1876	17.56
1876-77	0	0	0	2.29	0	0	3.26	0.75	1.01	0	0.03	0	7.34	1877	8.00
1877-78	0	0	0	0.80	0.81	1.34	9.87	9.74	3.58	1.29	0.06	0	27.49	1878	26.81
1878-79	0	0	0.48	0.80	0.72	0.27	3.86	3.48	5.85	1.24	1.58	0.09	18.37	1879	21.53
1879-80	0	0	0	0.52	1.77	3.14	2.51	1.64	2.13	8.70	0.76	0	21.17	1880	27.63
1880-81	0	0	0	0	0.52	11.37	4.26	2.34	0.80	1.58	0.03	0.22	21.12	1881	14.25
1881-82	0	0	0.16	0.69	1.16	3.01	0.79	1.72	3.98	1.11	0.08	0	12.70	1882	13.18
1882-83	0	0	0.18	1.50	2.98	0.84	1.93	0.59	2.72	1.81	2.92	0	15.47	1883	12.54
1883-84	0	0	0.30	1.14	0.21	0.92	3.40	4.87	6.38	3.40	0.05	2.91	23.58	1884	30.76
1884-85	0	T	0.17	1.78	0.21	7.59	2.36	0.19	0.52	4.20	0.05	0.10	17.17	1885	16.79
1885-86	0	0	0.02	0.13	6.88	2.34	6.20	0.35	1.20	4.50	0.15	0	21.77	1886	15.88
1886-87	0.07	0	0	1.69	0.77	0.95	1.21	9.16	0.72	1.68	0	0	16.25	1887	17.76
1887-88	0	0	0.47	0	1.08	3.44	4.73	1.21	3.97	0.13	0.67	0.08	15.78	1888	19.02
1888-89	0	0	1.03	0	4.16	4.04	1.17	0.75	6.94	0.84	1.08	0	20.01	1889	34.21
1889-90	0	0	0	5.98	4.01	12.44	8.69	4.39	3.94	0.79	0.58	0	40.82	1890	21.45
1890-91	0	0	0.10	0.10	0	2.86	0.90	9.06	2.57	1.95	0.35	0	17.89	1891	24.01
1891-92	0	0	0.65	0.02	0.65	7.86	1.88	1.55	2.49	1.01	1.57	0	17.68	1892	23.56
1892-93	0	0	0.03	1.45	7.67	5.91	3.09	3.68	6.49	1.92	0	0	30.24	1893	21.10
1893-94	0	0	0.09	0.14	2.74	2.95	7.42	6.62	1.07	0.94	0.61	0	22.58	1894	34.28
1894-95	0	0	1.75	3.03	0.72	12.12	9.50	3.23	0.05	1.61	0.38	0	32.38	1895	19.12
1895-96	0	0	0.31	0.33	2.08	1.63	8.89	0.24	2.94	5.00	0.83	0	22.25	1896	28.04
1896-97	0	0.46	0.52	1.31	4.87	2.98	2.02	5.76	6.42	0.06	0	0.05	24.45	1897	19.76
1897-98	0	0	0	2.61	1.00	1.84	1.46	3.04	0.64	0.25	0.94	0.19	11.97	1898	10.80
1898-99	0	0	1.57	0.81	0.55	1.35	4.21	0.37	9.02	1.02	0.67	0.71	20.28	1899	27.18
1899-00	0	0.02	0	3.89	4.70	2.57	5.55	0.84	2.19	1.23	0.55	0	21.54	1900	20.20
1900-01	0	0	0.50	1.64	5.39	2.31	3.95	5.82	0.75	1.88	0.81	0	23.05	1901	18.45
1901-02	0	0	0.75	1.25	2.08	1.16	1.92	7.41	3.53	1.91	1.20	0.06	21.27	1902	23.15
1902-03	0	0	0	1.85	3.37	1.90	6.30	2.45	6.83	1.15	0	0	23.85	1903	23.06
1903-04	0	0	0	0.29	5.18	0.86	1.42	6.97	7.32	1.10	0	0	23.14	1904	26.12
1904-05	0	0	3.97	2.25	1.03	2.06	3.63	4.18	5.23	1.82	2.47	0	26.64	1905	22.14
1905-06	0	0	0	0	2.29	2.52	5.15	3.49	5.66	0.56	1.40	0.69	21.76	1906	23.35
1906-07	0	0	0.03	0	1.37	5.00	5.90	2.04	8.88	0.20	0.03	0.57	24.02	1907	23.00
1907-08	0	0	0.09	1.76	0	3.53	2.83	3.02	1.49	0.42	0.39	0	13.53	1908	12.01
1908-09	0	0	0.15	0.29	1.44	1.98	15.74	7.33	2.98	0	0	0	29.91	1909	34.73
1909-10	0	0	0.72	0.72	1.63	5.61	4.57	1.46	3.78	0.13	0	0	18.62	1910	12.43
1910-11	0	0	0.05	0.51	0.29	1.64	16.14	2.03	5.07	1.19	0.35	0	27.27	1911	28.33
1911-12	0	0	0	0.05	1.05	2.45	3.53	0.94	3.14	1.31	1.46	0.76	14.69	1912	.....
										Average			21.23		21.21

(Government Record.)

RAINFALL AT SANTA CRUZ—ELEVATION, 20 FEET.

Santa Cruz County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1878	....	....	....	....	....	....	10.56	14.71	4.04	2.06	0	0		1878	37.03
1878-79	0	0	1.27	2.75	0.30	1.34	4.79	4.42	3.64	2.14	1.41	0.05	22.11	1879	23.77
1879-80	0	0	0	1.06	3.76	2.50	1.44	1.04	2.12	5.60	0.70	0	18.22	1880	23.89
1880-81	0	0	0	0	0.40	12.59	9.38	3.28	1.74	2.26	0	0.99	30.64	1881	26.22
1881-82	0	0	0.39	1.64	0.96	5.58	3.08	3.04	5.57	2.26	0.24	0.07	22.83	1882	21.07
1882-83	0	0	0.65	2.47	2.28	1.41	3.57	0.76	3.65	1.63	3.18	0.02	19.62	1883	16.79
1883-84	0	0	0.54	1.42	0.95	1.07	3.30	5.27	8.76	6.78	0.11	2.48	30.68	1884	37.73
1884-85	0	0.10	0.33	1.37	0.32	8.91	2.11	0.41	0.47	2.43	0.05	0	16.50	1885	18.87
1885-86	0.08	0	0.07	0.10	10.25	2.90	7.60	0.80	3.05	7.60	0.30	0	32.75	1886	23.44
1886-87	0	0	0	0.79	1.10	2.20	1.01	9.62	0.53	1.90	0.02	0	17.17	1887	19.71
1887-88	0	0	0.42	0.42	1.21	4.58	8.00	1.93	4.61	0.57	1.08	0.09	22.91	1888	27.89
1888-89	0	0	0.37	0	6.17	5.07	0.99	1.37	6.76	0.84	1.78	0	23.35	1889	44.26
1889-90	0	0	0	9.50	2.64	20.38	9.40	4.90	5.58	1.06	1.22	0	54.68	1890	25.30
1890-91	0	0	0.80	0	0	2.34	0.77	10.68	1.35	2.57	0.60	0.10	19.21	1891	25.90
1891-92	0	0	0.70	0.45	0.58	8.10	1.40	4.60	2.82	1.83	3.95	0	24.43	1892	27.98
1892-93	0	0	0.25	0.93	5.05	7.15	5.30	4.25	9.95	1.65	0.36	T	34.89	1893	30.41
1893-94	0	0	0.25	0.75	4.40	3.50	7.02	8.60	1.64	0.66	2.36	0.72	29.90	1894	41.48
1894-95	0.01	T	2.77	3.59	0.40	13.71	9.11	4.07	3.08	2.02	1.15	0	39.91	1895	24.14
1895-96	0	0	0.18	0.49	1.89	2.15	8.52	0.25	3.69	3.07	1.66	T	21.90	1896	31.86
1896-97	0.05	0.73	0.35	1.88	6.79	4.87	3.72	4.96	4.86	0.22	0.24	0.10	28.77	1897	18.43
1897-98	0	T	0.17	1.49	0.54	2.13	2.17	2.67	1.39	0.52	1.35	0.06	12.49	1898	13.87
1898-99	0	T	2.21	0.40	0.86	2.24	7.27	0.45	9.31	1.21	0.95	0.14	25.04	1899	34.55
1899-00	0	0.05	0	7.05	3.70	4.42	5.49	0.99	3.58	2.21	0.94	T	28.43	1900	25.80
1900-01	T	T	0.13	2.11	7.87	2.48	4.30	5.91	0.94	2.01	0.52	T	26.27	1901	20.28
1901-02	T	0	0.64	0.88	3.28	1.80	2.31	14.74	3.23	1.83	0.64	0	29.35	1902	29.82
1902-03	0	0	0	2.10	2.74	2.23	6.25	2.07	11.06	0.25	0	0	26.70	1903	29.22
1903-04	0	0	0	0.65	8.59	0.35	1.85	5.45	8.35	3.14	0.02	T	28.40	1904	32.12
1904-05	0	0.50	4.70	3.63	2.37	2.11	6.95	4.65	5.15	2.30	3.47	0.05	35.88	1905	27.18
1905-06	0.02	0	0	0	2.50	2.09	4.93	7.70	8.69	1.50	3.85	0.98	32.26	1906	38.78
1906-07	0	0	0.30	0	2.30	8.53	8.22	4.10	10.85	0.10	0.35	1.10	35.85	1907	33.62
1907-08	0	T	0.40	3.00	0	5.50	6.55	4.85	2.35	0.40	0.42	0	23.47	1908	22.22
1908-09	0	0	0.25	1.41	2.04	3.95	19.90	9.35	4.60	0.03	0	0.10	41.63	1909	50.41
1909-10	0	0	1.47	1.80	1.77	11.39	5.15	2.62	6.50	0.50	0	0.05	31.25	1910	18.57
1910-11	0	0	0.04	1.21	0.70	1.80	16.03	5.63	5.71	1.63	0.50	0.25	33.50	1911	35.41
1911-12	T	0	0	0.85	1.10	3.71	4.46	0.61	4.65	1.83	1.86	0.45	19.52	1912	.....

(Government Record.) Average.................27.66 28.18

RAINFAL AT SUNOL—ELEVATION, 227 FEET.

Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1889	0	0	....	....	....	....	0.67	0.35	5.52	0.80	2.75	0	....	1889	29.83
1889-90	0	0	0	4.69	3.69	11.36	8.36	4.98	3.63	1.21	1.07	0	38.99	1890	23.80
1890-91	0	0	0.90	0	0.14	3.51	3.78	1.06	1.89	2.23	0.54	0	14.05	1891	17.26
1891-92	0	0	1.00	0.12	0.37	6.27	0.77	1.21	3.87	1.12	1.81	0	16.54	1892	21.75
1892-93	0	0	0	1.80	6.35	4.82	2.67	2.79	6.43	2.09	0.24	0	27.19	1893	19.21
1893-94	0	0	0.07	0.18	2.09	2.65	6.64	6.38	1.32	0.73	1.36	0.30	21.72	1894	30.10
1894-95	0	0	1.45	1.39	0.60	9.93	6.87	2.73	1.70	1.66	0.69	0	27.02	1895	17.64
1895-96	0	0	0.37	0.45	2.00	1.17	7.17	0.32	1.10	4.05	0.88	0.08	17.59	1896	22.81
1896-97	0.20	0.30	0.46	1.33	4.31	2.61	2.17	4.32	5.75	0.42	0.35	0	22.22	1897	17.06
1897-98	0	0	0	1.68	0.48	1.89	1.78	2.38	0.75	0.30	1.04	0.21	10.51	1898	10.87
1898-99	0	0	0.80	1.11	0.52	1.98	3.19	0.31	6.72	0.99	0.56	0.11	16.29	1899	.....
1899-00	....	....	....	....	....	....	....								
										Average			21.21		21.03

From records S. P. Ry. Co.

RAINFAL AT SUNOL—ELEVATION, 227 FEET.

Alameda County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1898-99	0	0	0.83	0.86	0.83	2.10	3.40	0.30	9.05	2.00	0.83	0.21	20.41	1899	28.46
1899-00	0	0.17	0	3.90	4.30	4.30	3.29	1.33	2.10	2.12	0.76	0	22.27	1900	19.20
1900-01	0	0	0	2.58	5.21	1.81	2.97	7.61	1.51	2.57	1.11	0	25.37	1901	22.03
1901-02	0	0	0.93	1.31	1.92	2.10	1.27	5.84	4.23	1.28	0.66	0	19.54	1902	18.01
1902-03	0	0	0	0.76	2.67	1.30	4.88	1.51	5.95	1.95	0	0	19.02	1903	19.80
1903-04	0	0	0	0.06	4.73	0.72	2.17	6.04	5.88	2.20	0.36	0	22.16	1904	25.00
1904-05	0	0.32	2.57	1.96	1.22	2.28	2.70	3.48	4.88	1.38	2.50	0	23.29	1905	19.83
1905-06	0	0	0	0	2.42	2.47	6.83	3.74	6.91	1.65	0.52	0.67	25.21	1906	29.70
1906-07	0	0	0.25	0	1.69	7.44	4.44	3.18	11.03	0.55	0.70	0.50	29.78	1907	27.64
1907-08	0	0	0	1.43	0	5.81	3.53	2.76	1.32	0.31	1.02	0	16.18	1908	13.03
1908-09	0	0	0.48	0.38	0.84	2.39	11.72	6.03	3.30	0	0	0	25.14	1909	28.24
1909-10	0	0	0.71	0.89	2.05	3.54	4.79	2.34	3.72	0.49	0	0	18.53	1910	13.63
1910-11	0	0	0	0.68	0.23	1.38	14.83	3.26	6.38	1.41	0.26	0	28.43	1911	31.39
1911-12	0	0	0	0.90	1.10	3.25	2.90	0.41	3.23	1.90	1.24	0.88	15.81	1912	.....
										Average			22.22		22.77

Records of S. V. W. Co.

RAINFALL AT TRACY—ELEVATION, 64 FEET.

San Joaquin County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1879	....	....	....	....	....	....	2.32	2.07	2.15	0.96	0.66	0.27	....	1879	12.27
1879-80	0	0	0	0.32	1.55	1.97	0.69	1.03	0.62	2.77	0.25	0	9.20	1880	10.87
1880-81	0	0	0	0	0.43	5.08	1.85	1.61	0.95	0.76	0	0	10.68	1881	6.87
1881-82	0	0	T.	0.15	0.70	0.85	0.70	0.50	2.43	1.48	0.46	0	7.27	1882	7.42
1882-83	0	0	0.20	0.75	0.70	0.20	1.90	0.40	1.83	0.30	1.82	0	8.10	1883	7.70
1883-84	0	0	0.20	0.40	0.30	0.55	0.90	3.43	3.27	1.65	0.10	2.05	12.85	1884	14.81
1884-85	0	0.10	0	0.82	0	2.49	0.93	0.10	0.10	0.37	0	0	4.91	1885	7.95
1885-86	0	0	0	0	5.60	0.85	2.55	0.35	1.40	1.55	0	0	12.30	1886	6.85
1886-87	0	0	0	0.40	0.10	0.50	0.03	2.93	0.29	3.02	0	0	7.27	1887	8.75
1887-88	0	0	T	0	0.05	2.43	1.99	0.84	0.61	0	0.54	0.19	6.65	1888	9.08
1888-89	0	0	0.35	0	2.85	1.71	0.60	0.55	3.20	0.30	0.75	0	10.31	1889	17.86
1889-90	0	0	0	3.02	2.59	6.85	4.76	1.98	1.56	0.97	0.19	0	21.92	1890	12.74
1890-91	0	0	1.45	0	0	1.83	0.35	1.75	1.70	1.54	0.57	0.15	9.34	1891	10.00
1891-92	0	0	0.27	0	0.10	3.57	0.43	0.95	1.90	0.71	1.00	0.05	8.98	1892	12.25
1892-93	0	0	0	0	0	7.21	1.22	1.14	1.51	0.55	0	0	11.63	1893	6.20
1893-94	0	0	0.04	0	0.87	0.87	2.13	2.09	0	0.03	2.00	1.14	9.17	1894	13.92
1894-95	0	0	1.28	0.43	0.36	4.46	2.82	1.22	0.48	0.50	0.56	0	12.11	1895	7.61
1895-96	0	0	0.10	0.40	0.77	0.76	3.89	0	0.61	1.98	0.35	0	8.86	1896	*10.70
1896-97	0.12	0.17	*0.20	0.80	1.45	1.13	1.38	1.77	2.37	0	0	0	9.39	1897	*10.46
1897-98	0	0	0	1.24	*2.98	0.72	0.70	0.61	0.35	0	0.60	0	7.20	1898	3.87
1898-99	0	0	0	0.15	0.20	1.26	2.16	0.02	4.89	0.14	0.29	0	9.11	1899	14.99
1899-00	0	0	0	3.78	2.24	1.47	1.88	0.18	1.45	1.42	2.00	T	14.42	1900	11.58
1900-01	0	0	0.03	0.52	3.45	0.65	1.79	4.64	0.70	0.69	1.63	T	14.10	1901	11.22
1901-02	0	T	0.16	0.28	0.88	0.45	0.80	3.12	1.08	0.65	0.30	0	7.72	1902	7.77
1902-03	0	0.05	0	0.29	0.96	0.52	1.96	0.65	5.59	0.26	0	0	10.28	1903	10.23
1903-04	0	0	0	0	1.32	0.45	0.46	2.10	1.93	2.42	0	0	8.68	1904	12.83
1904-05	0	0.10	1.68	2.30	0.97	0.87	2.98	1.40	1.89	0.34	2.62	0	15.15	1905	10.88
1905-06	0	0	0	0	0.94	0.71	1.95	1.82	3.43	1.17	1.39	0.36	11.77	1906	14.87
1906-07	0	0	0	0	0.71	4.04	3.22	1.70	5.04	0.15	0	0.87	15.73	1907	13.44
1907-08	0	0	0	0.42	0	2.04	2.60	1.02	0.42	0.05	0.45	0	7.00	1908	7.28
1908-09	0	0	0	0.16	0.85	1.73	5.30	2.99	1.09	0	0	0.14	12.26	1909	14.98
1909-10	0	0	0.68	0	1.51	3.27	1.90	1.20	B. R.	0	0	0	....	1910	.....
1910-11	0	0	0.25	0.10	0.05	0.42	4.71	0.61	3.66	0.23	0.02	0.02	10.07	1911	10.39
1911-12	0	0	0	0	0.22	0.92	1.00	0.40	0.80	1.24	0.59	0.38	5.55	1912	.....
										Average..................			10.31		10.58

*Interpolated data.
(Government Record.)

RAINFALL AT UPPER CRYSTAL SPRINGS—ELEVATION 300 FEET.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1875-76	0	0	0	0.53	12.99	7.55	11.20	8.30	8.42	1.52	1.10	0	51.61	1876	37.28
1876-77	0	0	0	6.32	0.42	0	5.20	1.43	3.42	0.11	0.23	0	17.13	1877	18.31
1877-78	0	0	0	0.85	2.59	4.48	17.12	21.25	9.81	2.31	0.20	0	58.61	1878	56.21
1878-79	0	0	1.35	2.36	0.81	1.00	8.14	2.80	14 75	3.44	2.27	0	36.92	1879	46.67
1879-80	0	0	0	1.68	4.14	9.45	5.16	3.44	3.97	17.39	3.14	0	48.37	1880	51.66
1880-81	0	0	0	0	0	18.56	11.14	5.17	1.34	1.48	0.24	0.60	38.53	1881	29.52
1881-82	0.25	0	0.71	1.11	2.00	5.48	2.39	2.60	7.03	3.35	0.27	0	25.19	1882	25.20
1882-83	0	0	0	2.69	5.24	1.63	4.10	0.56	3.87	1.68	3.19	0	22.96	1883	18.44
1883-84	0	0	0	2.32	0.91	1.81	5.41	8.29	11.78	5.50	0.35	3.95	40.32	1884	50.83
1884-85	0	0	0.44	3.27	0.40	11.44	3.68	0.21	0.84	4.90	0.03	0.47	25.68	1885	26.00
1885-86	0	0	0.08	0.14	11.75	3.90	7.71	0.66	3.26	7.73	0.35	0	35.58	1886	24.02
1886-87	0	0	0	1.70	1.15	1.46	3.52	15.28	2.04	4.49	0	0.02	29.66	1887	34.96
1887-88	0	0	1.17	0	2.43	6.01	11.40	2.17	8.36	0.50	0.92	0.63	33.59	1888	36.33
1888-89	0	0	0.99	0	4.88	6.48	2.06	1.40	14.28	2.11	3.50	0	35.70	1889	62.95
1889-90	0	0	0	9.76	5.95	23.89	15.60	7.47	7.09	1.81	1.11	0	72.68	1890	37.93
1890-91	0	0	0.03	0	0.02	4.80	1.39	16.09	6.12	2.92	0.36	0.19	31.92	1891	38.43
1891-92	0.11	0	1.02	0.18	1.11	8.94	2.52	2.22	4.67	1.14	2.25	0	24.16	1892	35.98
1892-93	0	0	0.14	2.07	10.20	10.77	3.61	5.95	10.94	2.90	0.49	0	47.07	1893	34.03
1893-94	0	0	0.53	0.75	5.66	3.20	9.87	7.84	1.81	1.16	2.04	0.22	33.08	1894	47.94
1894-95	0	0	2.03	3.27	1.90	17.80	18.66	4.73	3.96	2.37	1.05	0	55.77	1895	36.89
1895-96	0.09	0	0.67	0.24	1.89	3.23	17.18	0.46	2.98	9.36	1.99	0	38.09	1896	48.13
1896-97	0	0.10	0.40	1.95	8.06	5.65	3.01	9.69	9.62	0.70	0.10	0.09	39.32	1897	31.64
1897-98	0	0	0	3.80	1.29	3.34	2.00	4.65	1.12	0.37	1.97	0.51	19.05	1898	16.01
1898-99	0	0	1.78	1.17	0.84	1.60	7.63	0.42	14.56	1.09	0.50	1.33	30.92	1899	40.09
1899-00	0	0.06	0	4.98	5.58	3.94	6.89	1.25	4.03	1.75	0.64	0	29.12	1900	29.43
1900-01	0	0	0.38	3.29	7.21	3.99	5.03	7.34	1.15	3.35	2.00	0	33.74	1901	25.92
1901-02	0	0	1.28	0.87	3.14	1.76	2.27	12.20	5.67	2.42	1.33	0.08	31.02	1902	34.05
1902-03	0	0	0	3.22	4.41	2.45	8.28	2.99	7.51	1.58	0	0	30.44	1903	30.91
1903-04	0	0	0	0.30	8.66	1.59	2.26	11.39	11.54	2.20	0.51	0.03	38.48	1904	44.40
1904-05	0	0.06	6.44	4.49	1.58	3.90	4.46	6.37	6.86	2.01	4.01	0	40.18	1905	30.98
1905-06	0	0	0	0	3.71	3.56	10.70	6.73	10.26	1.27	2.02	0.38	38.63	1906	43.32
1906-07	0	0	0.14	0	2.41	9.41	8.30	7.55	17.62	0.82	0.39	0.86	47.50	1907	44.68
1907-08	0	0	0.20	1.95	0.08	6.91	5.38	8.24	2.11	1.15	1.41	0.20	27.63	1908	26.01
1908-09	0	0.14	0.30	1.65	2.13	3.30	24.91	11.05	4.77	0	0	0	48.25	1909	52.26
1909-10	0	0	0.95	0.79	2.94	6.85	5.30	2.36	4.16	0.36	0	0.01	23.72	1910	15.38
1910-11	0	0	0.05	0.94	0.71	1.49	20.26	3.92	6.15	1.52	0.73	0.03	35.80	1911	38.35
1911-12	0	0	0	0.96	1.41	3.37	3.48	0.37	4.20	2.09	2.03	0.42	18.33	1912	.....
										Average			36.08		36.14

(P-86.)
Records S. V. W. Co.

RAINFALL AT WESTLEY—ELEVATION, 90 FEET.

Stanislaus County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1889	....	....	....	....	....	....	0.38	0.33	2.60	0.41	0.88	T.	.....	1889	14.19
1889-90	0	0	0	2.65	1.92	4.92	3.48	1.69	0.89	1.13	0.33	0	17.01	1890	9.27
1890-91	0	0	0	0	0	1.75	0.12	2.27	1.46	1.21	0.18	0.10	7.09	1891	8.98
1891-92	0	0	0.21	0.11	0.07	3.25	0.44	1.32	1.91	0.82	0.85	0	8.98	1892	13.42
1892-93	0	0	0.46	1.74	1.77	4.11	1.38	1.57	2.56	0.74	0.32	0	14.65	1893	8.29
1893-94	0	0	0.08	0	0.64	1.00	1.93	1.78	0.11	0.04	1.19	0.85	7.62	1894	12.25
1894-95	0	0	0.80	0.65	0.23	4.67	4.16	0.87	1.15	0.91	0.48	0	13.92	1895	9.14
1895-96	0	0	0.12	0.04	0.90	0.51	5.62	0	1.42	1.45	0.38	0	10.44	1896	16.65
1896-97	0.35	T.	0.31	1.95	4.16	1.01	1.60	2.46	2.03	0	0.11	0.08	14.06	1897	8.02
1897-98	0	0	0	0.86	0.13	0.75	0.53	0.58	0.68	0	0.65	0	4.18	1898	4.04
1898-99	0	0	0.12	0.39	0.20	0.89	2.37	0	3.17	0.20	0.50	0	7.84	1899	10.93
1899-00	0	0	0	1.50	2.31	0.88	1.77	0	0.55	1.09	2.04	0	10.14	1900	11.96
1900-01	0	0	0.65	0.10	4.38	1.38	1.71	3.70	0.28	0.54	0.97	0	13.17	1901	9.44
1901-02	0	0	0	0.44	1.43	0.37	0.73	3.35	0.83	0.61	0.11	0	7.87	1902	7.09
1902-03	0	0	0	0	0.76	0.70	1.51	0.92	5.10	2.02	0.07	0	11.08	1903	11.02
1903-04	0	0	0	0	1.08	0.32	0.41	1.53	3.07	1.27	0	0	7.68	1904	9.73
1904-05	0	0	1.59	0.32	0.73	0.81	2.12	1.87	2.21	0.40	1.60	0	11.65	1905	9.89
1905-06	0	0	0	0	0.75	0.94	2.19	2.12	4.63	1.56	0.99	0	13.18	1906	17.69
1906-07	0	0	0	0	0.92	5.28	5.18	1.39	3.55	0.24	0	0.31	16.87	1907	13.02
1907-08	0	0	0	0.78	0	1.57	3.05	1.08	0.49	0	0.67	0	7.64	1908	7.02
1908-09	0	0	0	0	0.54	1.19	3.93	3.09	1.03	0	0	T.	9.78	1909	.....
1909-10	0	0	0	0.35	Broken record	3.21	1.57	0.35	3.02	0	0	T.	.....	1910	6.08
1910-11	0	0	0.23	0.20	0.26	0.45	5.70	0.60	5.12	0.15	0	0.13	12.84	1911	12.59
1911-12	0	0	0	0	0.29	0.60	2.13	0.14	2.61	1.22	0.78	0.70	8.47	1912	.....
(Government Record.)										Average			10.73		10.49

RAINFALL AT WOODSIDE—ELEVATION 600 FEET.

San Mateo County, California.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season	Year	Annual
1893-94	....	....	....	....	....	....	....	....	....	....	....	....	34.01	....	.....
1894-95	....	....	....	....	....	....	....	....	....	....	....	....	49.27	....	.....
1895-96	....	....	....	....	....	....	....	....	....	....	....	....	32.12	....	.....
1896-97	....	....	....	....	....	....	....	....	....	....	....	....	37.93	....	.....
1897-98	....	....	....	....	....	....	....	....	....	....	....	....	18.31	....	.....
1898-99	....	....	....	....	....	....	....	....	....	....	....	....	28.36	....	.....
1899-00	....	....	....	....	....	....	....	....	....	....	....	....	28.09	....	.....
1900-01	....	....	....	....	....	....	....	....	....	....	....	....	29.92	....	.....
1901-02	....	....	....	....	....	....	....	....	....	....	....	....	33.68	....	.....
1902-03	....	....	....	....	....	....	....	....	....	....	....	....	31.09	....	.....
1903-04	....	....	....	....	....	....	....	....	....	....	To April 24th		39.17	....	.....
Records S. V. W. Co.									Average, July, 1893, to June, 1903				32.28		

OVERFLOW OVER SUNOL DAM.

Alameda Creek—Million Gallons.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1900-01	10	1	24	191	8,116	903	6,153	17,750	3,149	1,171	1,068	400	38,936
1901-02	168	42	....	....	9	354	3	8,670	12,954	2,162	806	304	25,472
1902-03	106	47	....	....	97	16	6,584	5,252	11,200	10,731	824	88	34,945
1903-04	31	....	....	....	399	7	123	7,675	14,954	4,885	1,637	196	29,907
1904-05	26	4	1	....	1	197	1,016	3,460	6,411	1,812	1,472	179	14,579
1905-06	3	1	....	....	....	3	15,940	6,974	23,780	8,455	2,325	1,084	58,565
1906-07	210	32	15	1	1	6,015	20,718	8,277	55,289	6,851	1,943	802	100,154
1907-08	596	239	37	41	184	1,418	4,196	3,714	3,171	556	308	9	14,469
1908-09	8	5	10	5	8	24	35,380	31,775	8,866	1,459	322	140	78,002
1909-10	113	1	4	38	28	2,952	10,276	4,028	5,082	1,978	613	151	25,264
1910-11	90	26	13	11	5	19	29,727	12,050	42,498	1,845	615	150	87,049
1911-12	112	91	49	42	62	84	818	538	2,555	556	130	6	5,043

OVERFLOW OVER NILES DAM.

Alameda Creek—Million Gallons.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1888-89	....	....	....	....	....	....	....	....	....	....	....	....	......
1889-90	....	....	....	....	....	40,731	77,019	36,726	20,879	5,113	2,864	1,103	184,435
1890-91	582	366	318	337	344	988	1,086	14,730	16,649	2,833	1,111	571	39,915
1891-92	185	13	....	....	....	3,223	1,595	1,542	6,002	3,843	2,205	413	19,021
1892-93	90	....	....	....	16,269	46,909	14,412	25,841	6,379	5,848	2,388	499	118,635
1893-94	291	161	111	52	148	413	19,322	44,022	4,558	978	542	320	70,918
1894-95	148	35	23	92	74	19,947	54,917	14,260	3,438	2,325	1,757	540	97,556
1895-96	202	37	41	134	142	192	22,074	2,193	2,328	11,170	2,702	519	41,734
1896-97	115	35	36	72	1,561	2,580	2,830	29,359	30,697	4,990	1,314	450	74,039
1897-98	208	59	43	67	24	78	204	826	556	141	45	5	2,256
1898-99	....	2	....	14	7	4	433	43	21,906	994	202	76	23,681
1899-00	16	....	....	33	511	1,901	11,462	575	2,280	632	323	54	17,787

FLOW PUMPED THROUGH BELMONT PUMPS.

No Slippage Deducted—Million Gallons.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1888-89	....	....	91	61	123	167	....	....	....	....	....	....	442
1889-90	....	....	....	....	....	....	41	....	....	....	....	....	41
1890-91	145	253	236	242	235	204	199	162	99	193	241	235	2,444
1891-92	244	227	201	205	198	191	158	270	228	177	222	232	2,553
1892-93	243	184	126	126	126	57	117	....	....	....	....	28	1,007
1893-94	233	240	169	151	146	132	58	....	19	155	162	156	1,621
1894-95	162	159	146	162	47	....	....	....	....	....	....	....	676
1895-96	86	240	230	238	233	241	121	....	....	....	....	132	1,521
1896-97	240	241	233	241	184	173	....	....	....	....	....	....	1,312
1897-98	....	156	156	154	156	43	....	145	184	233	242	226	1,695
1898-99	180	144	153	206	213	221	163	205	114	191	229	223	2,242
1899-00	231	231	217	197	113	135	117	194	149	222	233	226	2,265
1900-01	232	232	196	236	172	314	309	257	311	305	317	307	3,188
1901-02	317	317	288	289	289	319	321	291	318	313	325	287	3,674
1902-03	325	316	271	299	301	365	391	433	512	503	508	529	4,753
1903-04	533	428	335	325	382	501	516	468	504	496	517	502	5,507
1904-05	517	457	344	369	384	420	493	448	506	496	515	489	5,438
1905-06	478	429	301	265	255	290	370	460	507	301	130	377	4,163
1906-07	434	457	454	424	402	427	477	464	340	499	525	524	5,427
1907-08	492	523	504	501	502	490	466	480	518	506	520	502	6,004
1908-09	491	378	318	287	277	311	291	....	334	434	519	488	4,128
1909-10	477	483	464	502	458	463	522	472	527	505	521	498	5,892
1910-11	459	490	390	204	301	420	479	308	408	477	511	508	4,955
1911-12	462	524	454	508	510	527	519	490	510	501	519	498	6,022

OVERFLOW AT NILES DAM OR SUNOL DAM + BELMONT PUMPAGE.

Total Flow—Million Gallons.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1888-89	....	....	91	61	123	167	....	....	....	....	....	....	442
1889-90	....	....	....	....	....	40,731	77,060	36,726	20,879	5,113	2,864	1,103	184,476
1890-91	727	619	554	579	579	1,192	1,285	14,892	16,748	3,026	1,352	806	42,359
1891-92	429	240	201	205	198	3,414	1,753	1,812	6,230	4,020	2,427	645	21,574
1892-93	333	184	126	126	16,395	46,966	14,529	25,841	6,379	5,848	2,388	527	119,642
1893-94	524	401	280	203	294	545	19,380	44,022	4,577	1,133	704	476	72,539
1894-95	310	194	169	254	121	19,947	54,917	14,260	3,438	2,325	1,757	540	98,232
1895-96	288	277	271	372	375	433	22,195	2,193	2,328	11,170	2,702	651	43,255
1896-97	355	276	269	313	1,745	2,753	2,830	29,359	30,697	4,990	1,314	450	75,351
1897-98	208	215	199	221	180	121	204	971	740	374	287	231	3,951
1898-99	180	146	153	220	220	225	596	248	22,020	1,185	431	299	25,923
1899-00	247	231	217	230	624	2,036	11,579	769	2,429	854	556	280	20,052
(Niles Dam)													
1900-01	242	233	220	427	8,288	1,217	6,462	18,007	3,460	1,476	1,385	707	42,124
1901-02	485	359	288	289	298	673	324	8,961	13,272	2,475	1,131	591	29,146
1902-03	431	363	271	299	398	381	6,975	5,685	11,712	11,234	1,332	617	39,698
1903-04	564	428	335	325	781	508	639	8,143	15,458	5,381	2,154	698	35,414
1904-05	543	461	345	369	385	617	1,509	3,908	6,917	2,308	1,987	668	20,017
1905-06	481	430	301	265	255	293	16,310	7,434	24,287	8,756	2,455	1,461	62,728
1906-07	644	489	469	425	403	6,442	21,195	8,741	55,629	7,350	2,468	1,326	105,581
1907-08	1,088	762	541	542	686	1,908	4,662	4,194	3,689	1,062	828	511	20,473
1908-09	499	383	328	292	285	335	35,671	31,775	9,200	1,893	841	628	82,130
1909-10	590	484	468	540	486	3,415	10,798	4,500	5,609	2,483	1,134	649	31,156
1910-11	549	516	403	215	306	439	30,206	12,358	42,906	2,322	1,126	658	92,004
1911-12	574	615	503	550	572	611	1,337	1,028	3,065	1,057	649	504	11,065
(Sunol Dam)													

FLOW THROUGH SUNOL AQUEDUCT GAGED AT BRIGHTSIDE WEIR.

Million Gallons.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1906-07	462	495	472	460	424	422	471	447	362	509	543	524	5,591
1907-08	537	547	513	511	495	477	457	469	519	506	524	524	6,079
1908-09	521	51	345	306	287	276	321	145	396	474	531	493	4,146
1909-10	484	506	480	499	451	476	596	489	555	543	518	481	6,078
1910-11	447	291	....	....	....	284	417	310	396	474	542	517	3,678
1911-12	480	527	....	48	492	526	497	481	524	504	522	....	....

CALAVERAS CREEK AT CALAVERAS DAMSITE.

Run-off in Million Gallons—Drainage Area, 100 Sq. Mi.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1897-98	....	....	....	....	....	....	....	....	....	239	122	68	....
1898-99	22	10	9	15	8	11	3,157	314	9.456	2,334	574	464	16,374
1899-00	200	60	25	67	1,392	3,964	6,470	476	2,120	1,088	703	225	16,790
1900-01	34	16	15	88	5,376	649	6,257	5,336	1,726	576	1,264	402	21,739
1901-02	46	21	15	16	15	653	123	5,815	3,740	978	398	66	11,886
1902-03	13	8	8	8	336	512	2,706	3,892	3,768	4,804	547	433	17,035
(Hadsell)													
1903-04	241	139	37	132	927	219	224	5,345	8,121	2,827	1,453	264	19,929
1904-05	127	70	46	100	97	363	773	3,030	6,541	1,478	2,013	264	14,902
1905-06	112	46	30	31	32	70	9,783	2,492	9,555	3,122	1,086	603	26,962
1906-07	265	168	99	66	103	3,351	9,164	*2,193	*18,722	1,803	811	401	37,146
1907-08	109	51	45	52	92	774	2,754	2,368	2,106	439	280	133	9,203
1908-09	71	33	....	....	....	....	....	....	....	....	....	....	....
(Williams)													
1909-10	....	....	....	....	....	....	....	....	....	....	....	....	....
1910-11	....	....	....	....	....	....	....	....	....	....	....	....	....
1911-12	207	138	109	98	142	162	926	274	2,485	753	255	89	5,638
(Jones)													

*Incomplete records.

FLOW OF UPPER ALAMEDA CREEK.

Gaged at Diversion Point—Million Gallons.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1905-06	....	....	....	....	....	....	4,641	....	....	....	....	....	....
1906-07	....	....	....	....	....	....	....	....	....	....	....	....	....
1907-08	....	....	....	....	....	....	....	....	....	....	....	....	....
1908-09	....	....	....	....	....	....	....	....	....	....	....	....	....
1909-10	....	....	....	....	....	....	....	....	....	....	....	....	....
1910-11	....	....	....	....	....	....	....	....	....	....	....	....	....
1911-12 (Jones)	53	49	12	5	8	14	287	77	976	151	85	57	1,774

ARROYO VALLE—GAGINGS OF FLOW AT S. V. W. CO.'S DAMSITE.

Million Gallons.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Total.
1904-05	....	....	....	....	....	....	....	705	3,071	214	222	....	4,212
1905-06	....	....	....	....	....	....	6,848	1,056	8,587	1,538	197	24	18,250
1906-07	....	....	....	....	....	1,850	13,431	1,582	21,872	....	....	....	38,735
1907-08	....	....	....	....	....	377	2,057	1,398	....	....	....	....	3,832

DRAFT ON CRYSTAL SPRINGS RESERVOIR.

Million Gallons.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1888	....	....	....	....	....	....	....	....	....	....	....	....	....
1889	....	....	....	....	....	....	....	....	....	....	....	....	....
1890	67	124	240	216	220	220	155	89	83	87	84	75	1,660
1891	63	116	189	69	73	69	88	102	113	120	80	99	1,181
1892	138	15	88	146	119	96	106	143	191	191	149	231	1,613
1893	168	267	291	299	284	255	46	39	83	112	95	112	2,051
1894	182	232	233	107	175	166	181	196	208	173	262	286	2,401
1895	294	283	305	307	303	302	244	119	117	130	115	100	2,619
1896	213	327	342	335	349	200	143	120	80	76	111	134	2,430
1897	295	285	322	330	355	391	450	296	252	231	208	304	3,719
1898	328	166	209	222	409	428	443	459	383	176	246	309	3,778
1899	395	286	440	369	357	353	371	374	374	402	378	229	4,328
1900	259	154	257	171	196	196	213	210	231	204	252	104	2,447
1901	117	119	117	109	114	139	137	137	132	172	137	109	1,539
1902	95	80	109	109	115	159	165	169	187	174	79	37	1,478
1903	11	....	....	....	30	....	4	106	182	207	111	8	659
1904	3	11	16	12	22	26	21	90	193	186	234	320	1,134
1905	....	....	13	21	13	31	62	118	239	308	285	265	1,355
1906	179	36	77	33	78	89	101	89	91	128	115	77	1,093
1907	32	20	193	48	73	48	114	106	106	111	61	89	1,001
1908	79	82	66	59	73	82	112	218	248	303	254	272	1,848
1909	281	547	303	198	135	144	168	169	184	174	148	194	2,645
1910	76	156	146	153	172	212	267	210	290	469	327	244	2,722
1911	208	316	279	191	228	207	275	210	268	240	149	139	2,710
1912	121	110	187	314	304	415	....	....	....	....	....	....	*1,451

*Six Months' Total.

DRAFT ON SAN ANDREAS RESERVOIR.

Million Gallons.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1870	....	....	....	....	....	....	....	....	....	....	11	80	91
1871	83	75	76	78	109	92	79	107	108	116	97	89	1,109
1872	68	48	100	105	141	142	159	153	149	169	153	154	1,541
1873	153	145	158	158	149	151	146	164	147	159	136	132	1,798
1874	155	135	149	150	155	163	162	165	159	148	153	183	1,877
1875	154	146	158	168	198	194	201	200	208	241	216	230	2,314
1876	221	212	209	214	241	227	235	256	262	261	236	251	2,825
1877	251	235	291	281	269	265	241	224	227	129	104	91	2,608
1878	133	84	55	86	224	215	234	236	248	244	210	204	2,173
1879	195	169	205	209	233	249	245	267	276	273	235	223	2,779
1880	221	199	204	208	238	255	255	271	258	257	234	229	2,829
1881	239	199	232	234	269	250	284	294	287	296	247	243	3,074
1882	242	216	268	275	293	287	298	282	288	297	284	288	3,318
1883	275	161	123	117	116	151	173	150	182	168	133	112	1,861
1884	97	70	110	100	206	189	245	230	214	200	196	211	2,068
1885	226	200	222	213	257	250	285	159	231	28	32	34	2,137
1886	122	119	107	99	108	123	17	16	11	3	13	0	738
1887	15	33	51	84	132	222	233	237	231	293	246	249	2,026
1888	187	213	247	190	218	227	225	269	153	187	118	154	2,388
1889	....	....	....	....	....	....	....	....	....	....	....	....	1,019
1890	68	104	7	25	46	56	31	34	89	121	119	101	801
1891	84	24	86	89	98	105	130	112	108	115	109	103	1,163
1892	91	82	101	98	105	92	100	101	104	111	107	106	1,198
1893	101	84	89	103	149	171	175	173	171	177	164	167	1,724
1894	162	146	170	175	128	117	131	128	119	116	106	100	1,598
1895	110	103	118	123	151	157	199	192	226	205	202	213	1,999
1896	222	205	208	119	169	211	203	237	226	223	200	200	2,423
1897	192	176	204	227	230	229	234	233	231	227	220	221	2,624
1898	214	204	221	220	214	212	222	221	211	75	23	12	2,049
1899	3	57	15	....	....	3	9	17	20	81	91	111	407
1900	95	82	96	114	172	175	188	226	278	272	254	255	2,207
1901	248	227	270	260	271	270	278	257	247	268	234	223	3,053
1902	124	93	117	129	165	235	203	210	243	243	197	187	2,146
1903	163	134	152	173	190	212	226	230	229	230	213	228	2,380
1904	225	199	216	224	236	236	297	322	256	229	133	83	2,656
1905	84	80	76	69	30	219	267	294	294	307	290	292	2,302
1906	282	248	246	217	237	263	260	273	262	276	137	245	2,946
1907	242	225	242	251	261	251	257	253	216	313	297	322	3,130
1908	316	286	310	305	300	307	319	328	321	326	315	323	3,756
1909	291	276	341	349	361	357	375	372	262	237	214	321	3,756
1910	297	255	218	214	244	339	347	359	267	263	237	164	3,204
1911	224	253	393	447	431	421	367	373	366	341	296	250	4,162
1912	247	224	290	262	281	272	....	....	...	....	....	....	*1,576

*Six Months' Total.

DRAFT ON PILARCITOS RESERVOIR.

Million Gallons.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1867	....	....	....	....	84	87	86	90	9	88	89	78	611
1868	78	88	92	89	92	86	96	93	95	82	76	97	1,064
1869	103	80	100	99	130	114	121	110	10	133	87	90	1,177
1870	100	81	126	112	135	132	147	135	133	133	109	32	1,375
1871	32	28	55	25	31	64	75	60	64	70	44	30	578
1872	96	41	87	79	74	83	83	88	80	86	84	68	949
1873	88	56	81	93	67	79	82	77	75	66	60	68	892
1874	64	100	86	120	109	107	108	94	159	91	83	108	1,229
1875	72	76	98	114	114	115	135	142	109	98	78	68	1,219
1876	96	65	89	77	105	107	112	109	102	95	83	90	1,130
1877	71	37	95	69	65	52	52	47	63	52	42	56	701
1878	44	56	166	167	81	94	94	104	96	90	80	84	1,156
1879	72	58	60	72	83	110	98	107	98	103	84	73	1,018
1880	74	71	83	67	103	107	114	126	109	108	87	56	1,105
1881	93	75	96	85	116	107	120	139	121	112	93	82	1,239
1882	100	63	86	103	132	133	143	171	149	157	103	108	1,448
1883	90	106	97	132	128	142	144	151	155	112	134	110	1,501
1884	118	107	72	103	124	119	139	148	136	125	92	88	1,371
1885	142	149	127	111	155	138	151	139	126	117	86	103	1,544
1886	119	120	117	99	131	118	129	126	121	108	94	111	1,393
1887	122	99	107	112	131	140	142	135	129	140	108	70	1,435
1888	87	72	72	99	96	92	99	102	85	116	87	39	1,046
1889	Records incomplete.			S. V. W. Co.		Total used.							968
1890	110	81	81	103	123	138	152	135	166	146	114	114	1,463
1891	93	89	102	106	115	121	161	142	124	129	75	10	1,267
1892	6	5	11	26	31	38	18	16	31	34	....	....	216
1893	86	87	136	168	188	131	90	79	68	72	47	49	1,201
1894	52	50	85	103	34	....	141	159	141	50	48	30	893
1895	110	128	143	150	161	176	77	107	56	67	68	30	1,273
1896	57	67	56	76	142	165	142	121	125	135	87	97	1,270
1897	96	98	100	151	172	173	215	192	158	56	6	1	1,418
1898													236
1899													118
1900	Records incomplete.			S. V. W. Co. Totals used.									1,451
1901													1,219
1902													941
1903	123	152	156	160	177	159	150	136	110	82	44	41	1,490
1904	49	36	168	174	185	176	174	157	151	185	178	83	1,716
1905	64	160	185	176	131	154	160	175	179	133	74	62	1,653
1906	85	93	165	96	93	98	139	145	209	237	219	61	1,640
1907	74	160	93	122	74	72	75	180	203	199	205	139	1,596
1908	3	203	84	55	51	50	48	99	150	161	155	91	1,150
1909	148	46	69	97	79	51	182	211	205	212	167	62	1,529
1910	62	80	212	190	55	39	40	40	103	209	205	124	1,359
1911	73	41	44	158	148	155	160	160	155	161	155	127	1,537
1912	61	58	30	21	16	6	....	....	....	....	....	....	*192

*Six Months' Total.

DRAFT ON LAKE MERCED.

Million Gallons.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1877	....	....	....	....	....	....	....	....	1	97	92	91	281
1878	No records.												
1879													
1880													
1881													
1882													
1883	7	87	141	141	169	138	153	145	118	124	116	144	1,483
1884	156	157	155	158	79	77	82	103	100	100	92	95	1,354
1885	32	8	97	94	97	97	110	93	50	157	111	105	1,051
1886	....	....	....	....	....	3	147	154	118	129	109	115	775
1887	133	169	133	118	45	166	169	165	139	114	111	126	1,588
1888	184	130	96	168	182	172	176	151	3	....	....	....	1,262
1889	Records incomplete.			S. V. W. Co.		Total used.							712
1890	158	136	137	160	155	153	158	143	54	....	....	....	1,254
1891	10	89	17	....	....	....	....	....	....	....	17	100	233
1892	100	91	100	95	109	104	120	126	103	98	101	98	1,245
1893	5	....	....	....	....	58	100	100	96	100	96	100	655
1894	99	90	86	87	130	142	10	....	28	100	97	100	969
1895	33	....	....	....	....	....	....	....	....	....	....	42	75
1896	....	....	....	....	....	....	....	....	....	....	....	....	None.
1897	....	....	....	....	....	....	....	....	....	....	....	....	None.
1898													1,127
1899													1,330
1900													565
1901	Records incomplete.			S. V. W. Co.		Totals used.							116
1902													1,774
1903													1,696
1904													1,333
1905													1,096
1906	81	79	94	166	183	56	80	85	96	102	137	98	1,257
1907	94	89	96	124	118	109	117	159	196	68	37	21	1,228
1908	40	40	77	87	104	101	89	85	99	96	54	36	908
1909	64	9	7	68	102	81	91	94	183	176	185	83	1,143
1910	81	46	158	201	209	90	98	100	164	185	178	208	1,718
1911	122	74	19	....	42	41	110	102	110	125	153	222	1,120
1912	225	207	136	42	69	42	....	....	....	....	....	....	*721

*Six Months' Total.

Appendix I.

EVAPORATION AND TRANSPIRATION FROM THE WET LANDS IN LIVERMORE VALLEY

BY

C. H. Lee,

Hydrographer Los Angeles Aqueduct.

The following report contains a description of the method employed to determine the amount of water lost from the wet lands of Livermore Valley near Pleasanton.

The conclusions are based on a field examination of the area under consideration and application of the results of experiments carried on by Los Angeles Aqueduct Commission in Owens Valley, modified to correspond with local conditions.

Elevation of Water Table.

Four days (July 7 to 10, 1912) were spent near Pleasanton going over the ground studying conditions. The map prepared by F. W. Roeding of the Spring Valley Water Company showing the position of the contours of 9 ft., 6 ft. and 2 ft. depths to ground water June 13-17, 1912 (see accompanying Map No. 1), was carefully checked on the ground, by measurements to water surface in shallow wells and ditches, by actual tests with a soil auger, and by the knowledge of vegetation as influenced by shallow ground water, gained during three years' experience with a similar problem in Owens Valley, where extensive field measurements were made.

The location of the contours shown by Mr. Roeding is substantially correct. The only important change is between Tassajero and Alamo Creeks on the north side of the Valley where the 9 ft. contour was found to be north of the position shown for a distance of 1½ miles, the greatest deviation being ¼ mile, near the first north and south road from the Livermore-Dublin road west of Santa Rita. This change would add between 150 and 200 acres to the area between the 6 and 9 ft. contours. The final result would not be appreciably affected by changing the location of contour.

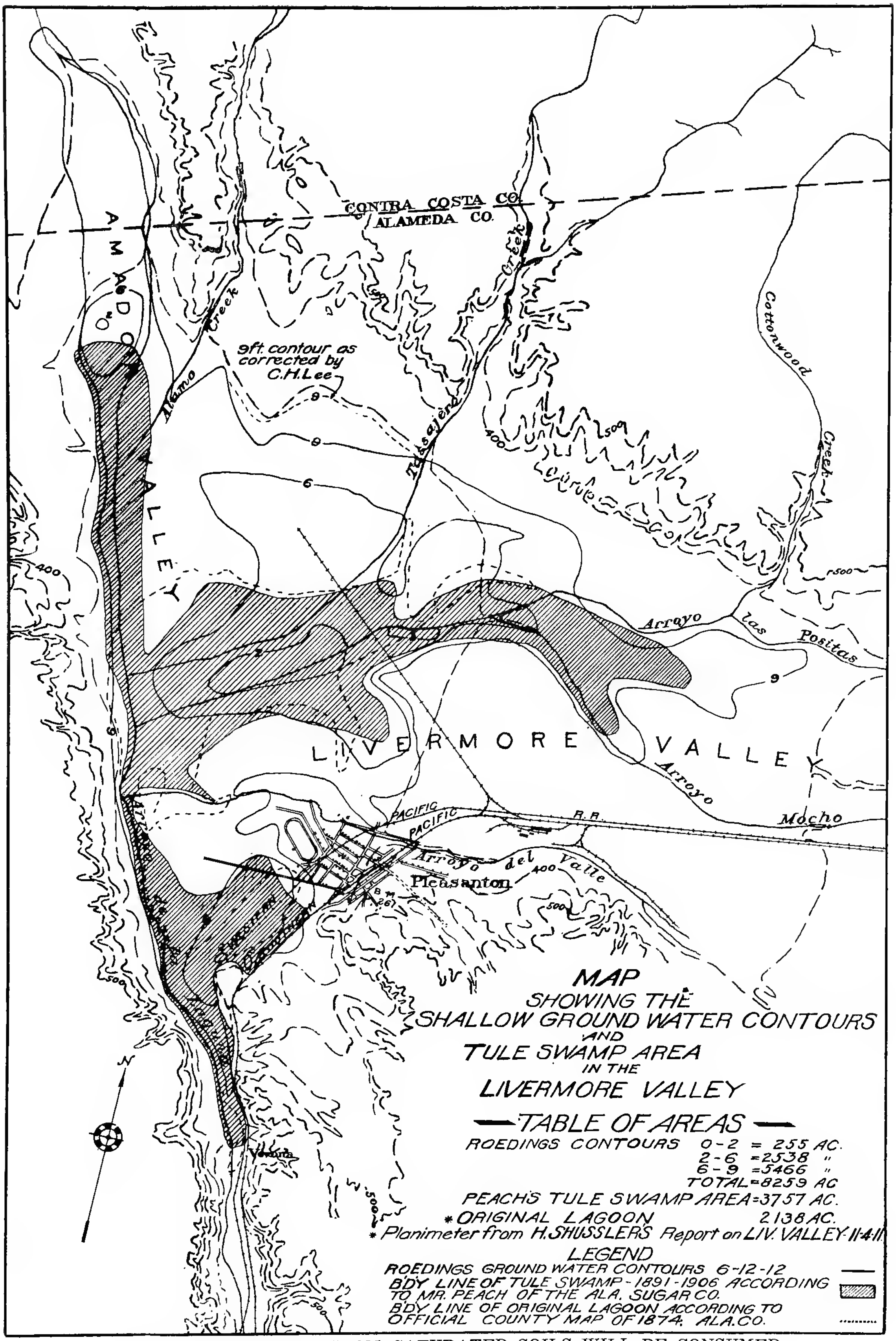
The drainage work carried on in the valley for agricultural purposes, since about 1907, has been so effective that the original tule swamp which existed in the center of the valley has almost entirely disappeared.

The original area of this swamp is an important factor in the computations, and an effort was made to determine its boundaries. Mr. Peach, who has been a resident of Pleasanton since 1891, in the employ of the Alameda Sugar Company, and more or less engaged in the drainage work, and familiar with early conditions, kindly went over the ground and indicated the approximate boundaries of the tule swamp prior to drainage. (See accompanying map.)

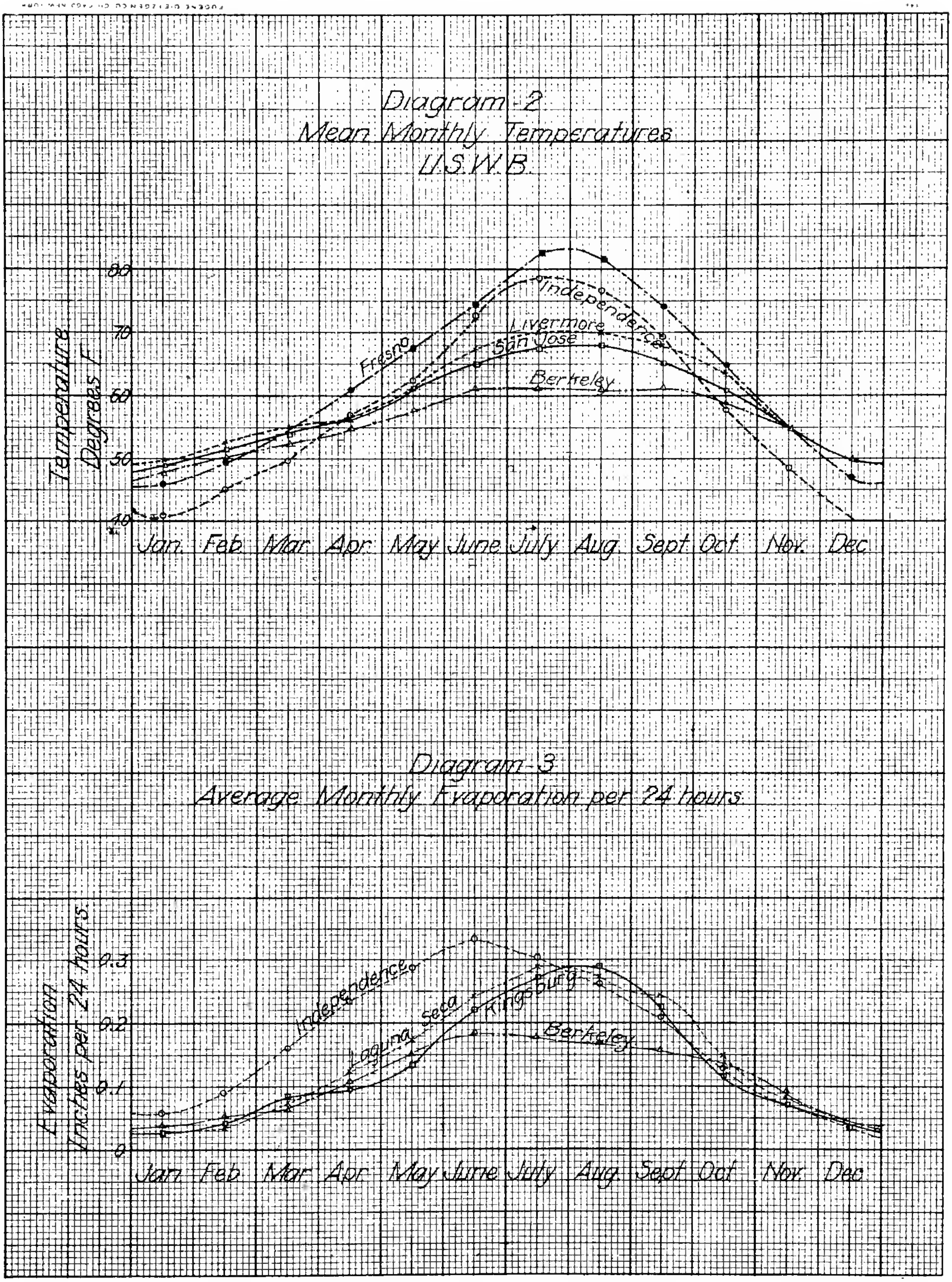
His recollections were quite definite in regard to that portion in the central valley north and west of Pleasanton, but not so definite when it came to the long arm reaching up Amador Valley, and the arm eastward toward Livermore from the Santa Rita Road.

Soil Capillarity.

In order to determine from what depth the soils of the valley would draw water by capillarity to supply evaporation, tests were made by borings with a soil auger.



THE EVAPORATION FROM SATURATED SOILS WILL BE CONSUMED.



CURVES SHOWING DIRECT RELATION BETWEEN MEAN MONTHLY TEMPERATURE AND EVAPORATION.

It was found that most of the soil contains a high percentage of clay, varying from the tenacious black adobe of the upper slopes, to the more friable peaty soils of the old swamp. A very small proportion along the arroyos is sandy clay. Inspection of the clay soils showed moisture within two inches of the surface anywhere within the 9 ft. contour depth to groundwater, indicating that eveporation was occurring from practically all of the areas within this contour. At the 6 ft. contour and within, the surface was quite moist where not cultivated and supported the vegetation typical of shallow ground water. Where the surface was tilled a kick of the heel would uncover moist soil. Every indication went to show that at the time of our visit, evaporation was occurring to a greater or less extent from the whole area within the 9 ft. contour, and our experience in Owens Valley confirms the opinion that such was the case.

Meteorological Conditions.

Consideration of meteorological conditions was the next step. A precipitiation record has been kept by the U. S. Weather Bureau at Livermore from 1870 to date. This will be found in Table 1, and from it has been prepared Diagram 1, showing graphically the seasonal variations, smoothed out by plotting three year progressive averages, computed by the formula,

$$b' = \frac{a + 2b + c}{4}$$

Temperature records are also available for Livermore, the monthly and annual averages being given in Table 2, together with those of San Jose, Gilroy, Independence, Fresno and Berkeley. These are plotted on Diagram 2.

Temperature and precipitation records have been kept at Pleasanton by Mr. Peach for the Alameda Sugar Company, but were not available at short notice. There are no records of humidity or wind movement in the Livermore Valley, nor evaporation.

Evaporation from Free Water Surface.

For the purpose of determining the value for the rate of evaporation from water at Pleasanton, the records at various points were considered (Table 3 and Diagram 3) in connection with the temperature records at nearby points.

The record at Kingsburgh in San Joaquin Valley, 20 miles southeast of Fresno, kept by the State Engineering Department, extending over four years, is reliable. It represents the evaporation from a reservoir surface. The average temperature at Fresno is higher than at Livermore and the range greater. The winters are slightly cooler and the summers considerably warmer. The humidity is probably about the same.

The record at Berkeley was obtained on the University Campus from a deep tank set in the soil and probably does not depart far from the results which would be obtained from a reservoir. The average temperature is less than at Livermore and the relative humidity is probably considerably greater on account of the ocean fogs which seldom extend into the Livermore Valley.

The record at Laguna Seca in mountains east of the Santa Clara Valley was made by the Bay Cities Water Company. It represents rather extreme conditions for that region. Two other records by the Company in the Santa Clara Valley show an annual depth of reservoir evaporation of 45 inches. The temperature in Santa Clara Valley at San Jose is slightly less than at Livermore and the humidity probably about equal. These records were made under conditions similar to those at Pleasanton.

On account of the strong dry winds blowing down from the San Ramon Valley every afternoon during summer, the annual evaporation from this region is probably greater than 45 inches. We have adopted a depth of annual evaporation of 48 inches, as taking place from open water surface in a reservoir in the vicinity of Pleasanton, with the monthly distribution observed in the Santa Clara Valley records. (Table 4.)

Soil Evaporation.

In determining evaporation losses from damp lands and swamp areas in the Livermore Valley there are two parts to be considered: First, the determination of evaporation and transpiration from the central swamp area supporting a rank vegetation of tule, bullrush, wild celery and willow; and second, the similar loss from the circumscribing zone of damp, more or less alkali soil supporting grasses of various kinds.

This year the area of swamp lands is so small that the first problem does not enter, but prior to effective drainage it was the most important of the two.

This swamp area lays over a portion of the artesian basin and had a permanent existence prior to drainage. It is shown on the official map of Alameda County, surveyed in 1874, as a lagoon covering much the same area as indicated by Mr. Peach.

The seasons 1873-74 and 1874-75 were both below normal in precipitation, so that the area there shown is probably slightly smaller than normal. The area indicated by Peach may be larger than normal on account of the heavy precipitation of the seasons 1888-89 and 1895-96, whose effect would hold over due to storage in the gravel and the retentive character of the soils to the north. It will be noted that the greatest extensions of the area are in the direction of the sources of supply, Arroyo Mocho and Alamo Creek.

The vegetation of the swamp area is that typical of flooded land, and has a rapid and rank growth. The new growth commences about March 1st and growth ceases probably in November. The rate of transpiration is greatest during the growing season and varies with the leaf area. It has been observed in Owens Valley that a continual shower of mist falls from willow trees during the summer months in the hottest part of the day, indicating that the rate of transpiration exceeds the rate of evaporation from the leaves. Actual measurement on alfalfa in Owens Valley shows the transpiration from blooming plants to be 0.49 inches per 24 hours on a day when the depth of water evaporating from a pan floating in Owens River was 0.30 inches. Measurements by German investigators show loss from meadow grass during the growing season to be 1.92 times that from water surface. (Bulletin No. 7, Forestry Division, U. S. Dept. of Agriculture.) Tule in the Livermore Valley, when burned, leaves a hollow tube of non-combustible ash, representing the amount of surplus mineral matter which accumulates in the plant during the growing season. All data points to a rate of transpiration from the swamp area greater than that from water.

We have concluded that a maximum rate of transpiration from the swamp occurs in July, of 1.75 times that from a water surface; that the increase from a very small value during the months of November to February commences about March 1st and increases rapidly at first and then more gradually toward the maximum, and that the decrease is gradual to the winter minimum.

In Table 5 is shown the resulting loss from the swamp area.

For the circumscribing zone of saltgrass and alkali land the conditions are almost identical with those of the Owens Valley experiments. The mean annual temperatures are nearly the same and although there is a greater range through the year at Independence, yet the mean temperatures of the critical months, April and September, are practically equal. Hence the general shape of curves of evaporation for shallow ground water fluctuation, is similar in the two localities and points of flexure occur at about the same time. The soil evaporation curves are constructed for the periods October 1st to March 31st and April 1st to September 30th, as in the Owens Valley.

The three conclusions justified by the Owens Valley experiments are:

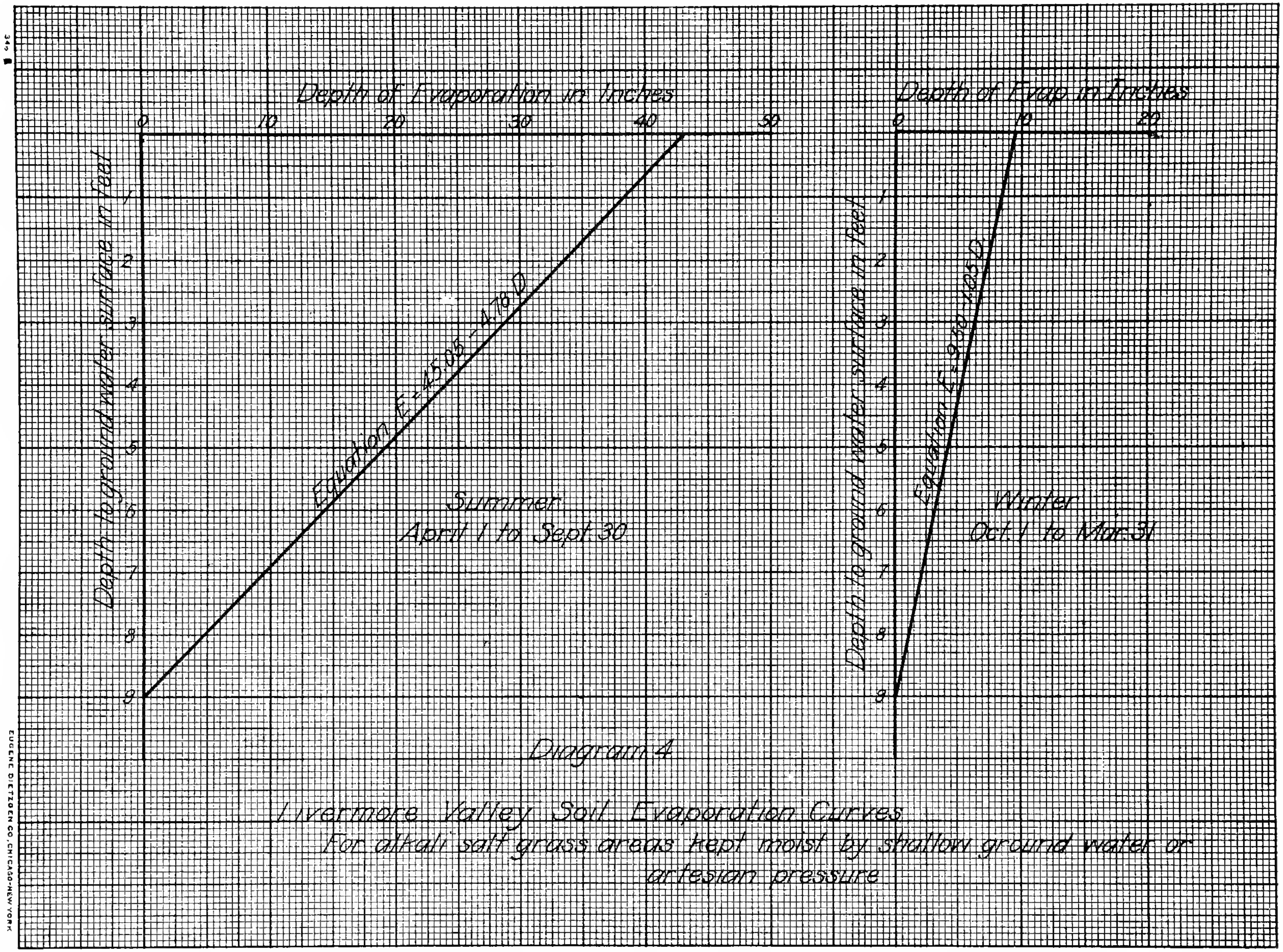
1. Soil evaporation decreases directly with depth to ground water surface.
2. There is a definite depth below which evaporation from ground water ceases.
3. The evaporation for soil growing saltgrass when ground water stands near the surface is 1.15 times that from a free water surface during the summer period, and 45% during the winter season of no growth.

In the Livermore Valley, the critical depth is about 9 ft. The period, October 1st to March 31st, includes part of a growing season, thus differing from the Owens Valley. With consequent larger evaporation we have adopted a value of 90% in these computations for this period. From this data Diagram 4 is constructed, using the free water surface evaporation as shown by Table 4.

Amount of Water Evaporated.

The total loss of water by evaporation was calculated for three conditions:

1. The conditions of depth to ground water, found by Roeding June 13-17, 1912.
2. The conditions as shown on official map of Alameda County of 1874.



TRANSPIRATION FROM SATURATED SOILS OF LIVERMORE VALLEY CONTINUED THROUGHOUT THE YEAR.

3. The conditions between 1891 and 1906 as indicated by Mr. Peach.

For the two latter cases Mr. Roeding's 9 ft. contour was adopted as representing the outside boundary of moist soil. This assumption cannot be far from right, since the hills limit material change, and the fact of no floods in the past winter, shows that the soil is kept moist from ground water alone. The areas are shown on the accompanying map.

The result of computations are shown on Table 5. For the first case, values for soil evaporation for the saltgrass area were read direct from Diagram 4. This was also done in cases two and three.

The depth of evaporation from the swamp area in the latter cases is determined as previously mentioned in this report. It is assumed that the depth of ground water on the outer edge of the swamp would be 3 ft., the depth at which tule would cease to grow. Depths to ground-water within given contours were averaged by judgment, where there was not uniform variation in depth.

June 15th represents the date of average annual ground water level according to the measurements in Owens Valley. The value of 10 M. G. D. for the evaporation loss under the conditions found by Mr. Roeding represents an average for the year 1912.

The result obtained from the area of the lagoon in 1874 is probably slightly smaller and that from Mr. Peach's area greater than the average. We conclude that a value of 21 M. G. D. represents the average annual loss by evaporation and transpiration from the wet lands of the Livermore Valley prior to effective drainage of the tule swamp in 1907.

The difference between 10 M. G. D. and 21 M. G. D. is partly due to the fact that the season 1911-12 is below normal in precipitation and further due to the drainage of the land by which water is conducted from the land as surface flow, which formerly was lost by evaporation

Conclusions.

In the foregoing it has been shown that drainage of the swamp lands and lowering of the ground water surface has reduced the evaporation from a yearly average of 20-24 M. G. D. to 10 M. G. D. in 1912.

It is intended, when operating the gravel basin as a reservoir, to permanently maintain the ground water surface at or near the 9-foot elevation, and thereby reduce the yearly evaporation loss to a minimum.

It is not believed, however, that the total amount of the evaporation loss, which occurred from the basin prior to drainage, could be recovered, since there are local areas which will not drain readily, and the cost of developing the last drop will be relatively too great.

A fair value of the proportion which can be economically saved would be 75% of the total or 15.7 M. G. D. per annum.

TABLE 1.

NORMAL TEMPERATURES, U. S. W. B.

July-June.	Total in inches.	Three-year progressive means, inches.	Departure from normal, inches.	July-June.	Total in inches.	Three-year progressive means, inches.	Departure from normal, inches.
1871-72	19.06	....	...	1892-93	26.29	20.99	+5.17
1872-73	10.69	13.17	—2.65	1893-94	17.16	21.24	+5.42
1873-74	12.26	11.72	—4.10	1894-95	24.37	20.56	+4.74
1874-75	11.67	13.90	—1.92	1895-96	16.35	18.59	+2.77
1875-76	19.99	14.42	—1.40	1896-97	17.28	15.00	—0.82
1876-77	6.01	12.42	—3.40	1897-98	9.11	11.19	—4.73
1877-78	17.66	12.86	—2.96	1898-99	9.27	10.09	—5.73
1878-79	10.11	13.46	—2.36	1899-00	12.72	13.61	—2.21
1879-80	15.98	14.63	—1.19	1900-01	19.72	17.24	+1.42
1880-81	16.45	15.14	—0.68	1901-02	16.80	16.89	+1.07
1881-82	11.70	13.43	—2.39	1902-03	14.25	14.66	—1.16
1882-83	13.86	15.54	—0.28	1903-04	13.33	14.18	—1.64
1883-84	22.75	17.84	+2.02	1904-05	15.81	16.07	+0.25
1884-85	12.01	15.74	—0.08	1905-06	19.32	19.40	+3.58
1885-86	16.17	13.88	—1.94	1906-07	23.14	18.88	+3.06
1886-87	11.17	12.91	—2.91	1907-08	9.93	15.39	—0.43
1887-88	13.13	13.31	—2.51	1908-09	18.58	15.39	—0.43
1888-89	15.81	18.35	+2.53	1909-10	14.50	17.22	+1.40
1889-90	28.66	21.82	+6.00	1910-11	21.28	....	...
1890-91	14.16	17.81	+1.99	1911-12	....	....	...
1891-92	14.25	17.24	+1.42	Mean	15.82		

TABLE 2.

NORMAL TEMPERATURES, U. S. W. B.

Station.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Livermore	49.3	51.6	53.8	56.9	61.4	67.6	70.1	69.6	68.2	62.8	54.9	50.5	59.7
San Jose	48.3	50.6	53.7	56.7	60.7	65.0	66.9	66.7	64.7	60.3	54.4	49.9	58.2
Gilroy	46.5	49.3	53.7	57.8	62.5	67.0	68.8	67.9	66.0	60.3	52.8	48.0	58.4
Independence	40.4	44.6	49.4	56.8	62.8	72.6	78.6	76.2	68.9	58.7	48.6	40.2	58.1
Fresno	45.4	49.2	54.9	61.2	68.4	75.8	82.0	81.2	74.3	64.7	54.6	47.8	64.4
Berkeley	47.6	49.7	51.7	54.0	57.3	60.9	61.0	60.9	61.3	58.9	54.6	48.9	55.6

TABLE 3.

MEASURED RATES OF EVAPORATION FROM WATER SURFACES.

	INDEPENDENCE.			KINGSBURGH.			BERKELEY.			LAGUNA SECA.		
Month.	Total in inches.	Rate in inches per 24 hours.	% of annual evap. each month.	Total in inches.	Rate in inches per 24 hours.	% of annual evap. each month.	Total in inches.	Rate in inches per 24 hours.	% of annual evap. each month.	Total in inches.	Rate in inches per 24 hours.	% of annual evap. each month
January	1.68	.054	2	0.81	.026	2	1.00	.032	2	1.00	.032	2
February	2.45	.088	4	1.18	.042	2	1.36	.048	3	1.00	.036	2
March	4.92	.159	7	2.54	.082	5	2.11	.068	5	2.60	.084	5
April	7.18	.239	11	2.76	.092	6	3.14	.105	8	3.70	.123	7
May	8.94	.288	13	4.22	.136	9	4.70	.152	11	5.20	.168	10
June	10.00	.334	15	6.66	.222	14	5.68	.189	14	7.30	.243	14
July	9.45	.304	14	8.37	.270	17	5.52	.178	13	8.90	.287	17
August	8.10	.261	12	9.05	.292	18	5.09	.164	12	8.30	.268	16
September	6.45	.215	10	6.69	.223	14	4.65	.155	11	7.30	.243	14
October	4.05	.130	6	3.56	.115	7	4.27	.138	10	3.60	.116	7
November	2.48	.083	4	2.13	.071	4	2.68	.089	7	2.10	.070	4
December	1.54	.050	2	1.18	.038	2	1.35	.044	3	1.00	.032	2
Total	67.24	.184	100	49.15	.134	100	41.55	.114	99	52.00	.142	100
Reference:	Eng. News, Oct. 12, 1911.			Eng. News, Aug. 13, 1908.			U. S. D. A., office of Exp. Station, Bul. 177, page 36.			Eng. News, Feb. 29, 1912.		

TABLE No. 4.

ASSUMED EVAPORATION FROM WATER SURFACE AT PLEASANTON.

Month.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An. nual.
Per cent of annual	2	2	5	7	10	14	17	16	14	7	4	2	100
Evaporation, inches	0.96	0.96	2.40	3.36	4.80	6.72	8.16	7.68	6.72	3.36	1.92	0.96	48

TABLE 5.

TOTAL VOLUME OF EVAPORATION FROM MOIST AND SWAMPY LANDS OF LIVERMORE VALLEY.

			Depth of evaporation, inches.			Equivalent flow for one year.		
Enclosing contours.	Area in acres.	Average depth to ground water, in feet.	Summer.	Winter.	Total.	Sec. feet.	M. G. D.	Date and authority for areas.
0-2 feet	255	1.5	36.0	8.0	44.0	1.29	0.83	
2-6 feet	2,538	4.0	24.0	5.5	29.5	8.63	5.57	F. W. Roeding.
6-9 feet	5,466	7.5	7.3	1.7	9.0	5.67	3.66	June 13-17, 1912.
Total	8,259	—	—	—	—	15.59	10.06	Official Map,
Tule swamp	2,138	Surface	—	—	66.0	16.23	10.50	Alameda Co.,
3-9 feet	6,121	5.5	17.0	3.8	20.8	14.67	9.48	1874.
Total	8,259	—	—	—	—	30.90	19.98	Mr. Peach,
Tule swamp	3,757	Surface	—	—	66.0	28.52	18.42	1891 to 1906.
3-9 feet	4,502	6.0	14.5	3.3	17.8	9.23	5.96	
Total	8,259	—	—	—	—	37.75	24.38	

Appendix J.

REPORT BY J. B. LIPPINCOTT, ASSISTANT CHIEF ENGINEER OF THE LOS ANGELES AQUEDUCT, ON ERRORS IN COMPUTATION OF FLOW OF ALAMEDA CREEK, APPEARING IN WATER SUPPLY PAPER No. 81

San Francisco, Cal., Sept. 28, 1912.

S. P. Eastman, Esq., Vice President & Manager,
Spring Valley Water Co.

Dear Sir: Mr. John R. Freeman and Mr. Cyril Williams, Jr., in their reports to the Board of Army Engineers who are to report to Secretary of the Interior on the Application of the City of San Francisco for rights of way for the Hetch Hetchy aqueduct, have called attention to differences in estimated flow of Alameda Creek at the Niles Dam as computed by the Engineers of the Spring Valley Water Company, and those published in the U. S. Geological Survey Water Supply Paper No. 81, edited by myself.

The purpose of publishing Water Supply Paper No. 81 was to assemble and preserve all data relative to the water supply of California, including not only official records of the State and Federal Government, but also all private records that could be obtained.

Data Used as Basis of Water Supply Paper No. 81.

In making this compilation it was found that, in a certain law suit tried in Alameda County, entitled "Clough vs. Spring Valley Water Company", involving water rights to Alameda Creek, testimony had been introduced showing gage heights observed by the Spring Valley Water Company on the Niles Weir intermittently from 1889-1900, inclusive. No computations were given in this evidence for the discharge over the weir. The gage height notes referred to the length of the weir as 60 feet, except in certain cases where in low water the length was reduced by flash boards. As far as I remember, there were no drawings giving the dimensions of this weir that were available, and the true conditions at the weir were not known at the time of the computations in the office of the U. S. Geological Survey.

In presenting the estimates in Water Supply Paper No. 81, the following statement is given, (Page 32):

> "When the water reaches high stages it fills the rectangular weir opening and flows over the top of the walls of the dam on the side, so that the large flood measurements that have been computed contain considerable elements of error. The measurements of smaller volumes, however, are doubtless more accurate."

And again on Page 33:

> "While the record is not considered perfect, it is the best obtainable and, in view of the extent of the data, it is deemed to be worthy of publication."

Effort has been made for the past few months to obtain the original computation books of the U. S. Geological Survey, in which these flows are estimated, and they have just lately been found in their Los Angeles Office. They are entitled, "U. S. Geological Survey, Hydrographic Branch, River Heights Observations", and they are numbered 281, 282, 283 and 284. The records of gage heights therein, together with length of weir, have been compared with "Exhibit No. 11", Page 1078, Vol. 2, of the Transcript of Appeal to the Supreme Court of the State of California, in the case of Jane R. Clough vs. Spring Valley Water Company, and, with few unimportant exceptions, are found to be an accurate copy. It has also been compared with the Company's office records and it practically agrees with them.

This exhibit is a record of gage heights and not of discharge. I do not remember who made the computations for the Geological Survey and no name is signed to this record.

On the front page of U. S. Geological Survey record book, No. 281, there is given a sketch of the Niles Weir which was used in these computations, a photo copy of which is attached to this letter. (See page 18.) It will be noted that the sides of the weir are shown 13½ feet high. No authority for this section can now be found. The flows are computed for a 60-foot weir, except in instances where the exhibit shows the weir to be less than 60 feet. The Francis formula was used. An inspection of the computations clearly shows that, in no case, was the flow over the weir considered to be more than 60 feet in length. In only one instance, in Exhibit No. 11, is a greater width than 60 feet indicated. This was between March 16th and 18th, 1899, inclusive, and also between March 20th and 30th, 1899, inclusive. This is also shown on Page 24 of Book 283. During this period the stream was in flood and a maximum gage height of 7 feet is given. In both of these instances, the Geological Survey computer questioned the length of the weir and has eliminated the record for that period. This month's record is also eliminated in Water Supply Paper No. 81 and marked "incomplete"

More Complete Data Now Available.

Measurements have been lately made of the Niles Weir by representatives of the various parties to this discussion and the section shows that whenever the head of the gage exceeds 12 inches, the weir is increased in length from 60 feet 2 inches to 131 feet 6 inches, and when the head is increased 23 inches more the total length of the weir becomes approximately 166 feet. This explains why the computations of the Geological Survey are markedly less in amount for the large flows on this weir than the computations made by others who have had the detailed dimensions of the weir and who have properly used these increased lengths.

While Water Supply Paper No. 81 states, "when the water reaches high stages, it fills the rectangular weir opening and flows over the top of the walls of the dam on the side, so that all flood measurements that have been computed contain considerable elements of error", yet there was no exact understanding at the time of the U. S. Geological Survey Computations of how excessive these extra amounts really were. This error is greatly regretted.

When I took up with others, in February, 1912, the study of the available water supply of the Livermore Valley, it was considered that the measurements and computations made by the Engineers of the Spring Valley Water Company, who were familiar with the weir and all the local conditions during the period of observation, were the more exact.

The weir is irregular and defective and, at best, computations of flow over it are only approximations. The computations of the Spring Valley Water Company had been used by Mr. Schussler, Mr. Williams and Mr. Herrmann and were, therefore, a common basis for study.

Computations of the flow over this weir have been made during the past few months by G. G. Anderson, Prof. Jos. N. Le Conte, of the State University, and Mr. F. C. Herrmann, Chief Engineer of the Spring Valley Water Company, have also made computations based on the flow over models of 1/19 the size of the Niles Weir and of its surrounding conditions, and a further study has also been made by a committee of Engineers, consisting of Mr. C. E. Grunsky, Prof. Chas. Marx and Prof. C. G. Hyde. In view of these four studies and of the amount of time required to again go through all the records the flow is not recomputed, but it is recommended that the weir be rated by your engineers by actual river measurements, for the sake of future computations.

For the period extending from November, 1889, to June, 1911, the mean flow as determined by the computations of the Spring Valley Water Company, for the Niles and Sunol Weirs, was 137.7 M. G. D. The flow for this same period, by Mr. Anderson, was 158.0 M. G. D. The flow computed from the Le Conte and Herrmann models was 150.2 M. G. D. Each of these parties have filed report giving their methods in detail. A table is attached presenting a summary of their conclusions.

The results of the computations made for the City by the Engineering Committee, above referred to, are not available to your Company. As your computations have been used by Mr. Freeman and Mr. Williams, presumably they are confirmed. These computations by Messrs. Hyde, Marx and Grunsky are valuable and should be presented to the Board of Engineers.

It is safe to accept the data presented by the

Spring Valley Water Company in its table, which has their serial number A-163, and which has been extensively used in the study of the water supply available from Alameda Creek.

Efforts were made by Mr. Mulholland, Mr. Herrmann and myself to confer with Mr. Freeman concerning differences of opinion that have arisen relative to the available water supply of Livermore Valley, but although two dates were set, to our regret Mr. Freeman notified us of his inability to meet us.

As the published records of the Geological Survey were not used by any of the Engineers involved in this study, it is singular that so much time and attention should have been given to them, especially as this published record distinctly disclaims accuracy.

A copy of this letter will be sent to the Hydrographic Branch of the U. S. Geological Survey with the request that they give due notice of the facts contained herein.

Yours very truly,

J. B. LIPPINCOTT.

COMPARATIVE ESTIMATES OF FLOW OF ALAMEDA CREEK.

Year	Unrevised S. V. W. Co.	Anderson	Le Conte and Herrmann	U. S. G. S.
1889-90	153,634	184,476	165,907	93,202
1890-91	36,590	42,359	38,931	25,250
1891-92	19,348	21,574	20,905	14,749
1892-93	102,039	119,642	117,511	......
1893-94	55,638	72,539	59,202	......
1894-95	81,565	98,232	86,422	62,177
1895-96	37,231	43,255	39,967	25,740
1896-97	63,825	75,351	67,771	42,422
1897-98	3,732	3,951	4,498	......
1898-99	24,623	25,923	23,091	......
1899-00	14,960	20,052	19,085	12,078
1900-01	31,828	42,124	40,038	......
1901-02	19,793	29,146	30,861	......
1902-03	23,199	39,698	37,854	......
1903-04	37,771	35,414	36,464	......
1904-05	20,254	20,017	20,451	......
1905-06	63,134	62,728	67,662	......
1906-07	102,917	105,581	104,856	......
1907-08	21,189	20,473	20,703	......
1908-09	83,989	82,130	79,470	......
1909-10	33,949	31,156	32,536	......
1910-11	74,852	92,004	92,425	......
Av. Yearly.	50,275	57,628	54,846	39,374
Av. Daily	137.7	158.0	150.2	107.7

NOTE: Run-off of Alameda Creek, plus Belmont pumps.

Department of the Interior,
United States Geological Survey,
Washington.

Water Resources Branch. October 17, 1912.

Mr. J. B. Lippincott, Assistant Chief Engineer,
Bureau of the Los Angeles Aqueduct,
Central Building, Los Angeles, Cal.

Dear Mr. Lippincott: Your letter of October 10, in regard to errors in published data for Alameda Creek, arrived just in time to stop the republication of these data in the special Water Supply Papers which are now being prepared, covering all available stream-flow data in the State. The time is too short to make any investigation of the matter, as the report which will contain these data is now in proof, so we have cut the records out and substituted the inclosed statement.

I am sending to Mr. McGlashan at San Francisco the data which you submitted with your letter, so that he may look into the matter, and, in case you desire the material returned to you, you can write to him for it.

Very truly yours,

JOHN G. HOYT,

Acting Chief Hydrographer.

Alameda Creek, in Alameda County, Cal.

Estimates of discharge for 1889-1900 for Alameda Creek at Niles Dam have been published in Water-Supply Paper No. 81. These estimates were computed by engineers of the United States Geological Survey from gage height records presented as Exhibit 11 in a suit entitled "Clough vs. Spring Valley Water Co. of San Francisco," tried in the Alameda County Superior Court, in the fall of 1901.

Since the proof of this report has been received, attention of the Survey has been called to the fact that the published estimates do not agree with estimates made by other parties. Upon investigation it was found that the base data used were incorrect and that the flood discharge was much greater than the published estimates. Lack of time before this report goes to press renders it impossible to revise these estimates, and they are therefore omitted from this report.

OFFER OF SPRING VALLEY WATER COMPANY TO SELL ITS WORKS TO THE CITY OF SAN FRANCISCO

San Francisco, Cal., September 14, 1912.

Honorable James Rolph, Jr., Mayor, Percy V. Long, City Attorney, Thomas Jennings, Chairman Finance Committee, Alexander T. Vogelsang, Chairman Public Utilities Committee, and Curtis H. Lindley, Esq., Comprising the City Advisory Water Committee, and the Members of the Board of Supervisors of the City and County of San Francisco,

Gentlemen:

Regarding the Purchase of Works by the City.

At the meeting of the board of directors of the Spring Valley Water Company, held on the 15th day of August, 1912, your communication dated August 9th, 1912, was referred to a special committee, theretofore appointed to represent the company in the pending negotiations with the city for the purchase of the company's works. The committee was not able to make its report to the board until the 12th day of the present month, on which date a special meeting was held for the purpose of receiving it, and to act upon the offer contained in your letter of August 9th. The board of directors, at that meeting, unanimously resolved that it could not, in justice to its stockholders, accept the offer made by you, and, by formal resolution, under authority with which it has been invested by the stockholders by resolution passed at the annual meeting in April of this year, authorizes the offer which follows, namely:

To sell to the City and County of San Francisco all of the property of the Spring Valley Water Company except, (1) Blocks 1221-2 and 3, 1285-6 and 7, Outside Lands, all properties bounded by or fronting upon Sloat Boulevard, or Junipero Serra Boulevard, and all the Lake Merced Ranch, other than the two Merced Lakes and a strip of land around them, the lakes and such strip containing an area of about five hundred and fifty acres (the strip around the lakes will be ample for park purposes and to prevent pollution of the water); (2) all money and other personal property owned by the company,—for the price named in your offer, to wit, thirty-eight and one-half million dollars.

In making this offer, the directors share with you the wish that controversies in water matters may cease, and that mutual confidence and co-operation in the upbuilding of our city may prevail.

When the subject of purchase was first broached by the present city administration, the company informed the Advisory Committee, acting on behalf of the city, that J. G. White & Company had been employed by the company to make a detailed inventory and appraisal of all the company's properties, and that, when their report was completed, the company would be better able to fix a price at which it would be willing to sell. While negotiations have been proceeding between the city and the company, J. G. White & Company have pursued their investigations and have proceeded so far as to make a partial report on the value of the company's holdings; and while their work has not been entirely completed, it has proceeded so far as to enable them to advise us that the value of the properties exceed sixty million dollars. This report deals with all of the elements of the company's property, and is the most exhaustive and detailed that has ever been made.

It has always seemed important to us that a careful inventory and appraisement of the properties should be made, in order that the city on the one hand, and the company on the other,

might have some substantial basis for negotiations looking to the acquisition of the property by the city. It is not disclosed by your communication that any valuation has been made by anyone in the city's behalf. In the early history of our negotiations, we were informed by the chairman of your Advisory Committee that they were tentatively considering a plan to appoint a board, consisting of three engineers, of whom John R. Freeman should be one, the others to be selected by him, subject to the approval of the Board of Supervisors; and that this board of engineers be intrusted with the duty of determining and reporting to the Board of Supervisors the value of the properties of the company. This suggestion met with our unqualified approval. We thought then, and still think, that the opinion of a board, thus constituted, would command respect, and have very great educational value. At a later date we were informed that those representing the city had determined not to have an appraisement made in the manner theretofore suggested, but that they were considering, tentatively, a new plan by which a joint effort be made to reach an agreement on value, and that, to accomplish this purpose, Mr. Freeman be appointed by the city to act for it, and that an engineer to act with him be appointed by the company to represent it; that these two engineers should agree upon values of all the elements of the company's properties upon which they might be able to agree; that a list of properties as to which they could not reach an agreement be made; and that a third engineer be selected by the two, to act with them, and a majority of the three thus appointed should fix the values of any of the properties upon which the first two might not have been able to agree. This suggestion also met with the hearty approval of the company, and it was considering the selection of an engineer to act with Mr. Freeman when it received word from the chairman of the Advisory Committee that the committee had concluded not to recommend this plan, and, because of that notification, nothing further was done in that direction.

We consider it a matter of very great regret that one of these plans was not pursued. Although a valuation arrived at as a result of either of them would not have been binding upon either of the parties, it would have commanded respect, and would probably have afforded a substantial basis for arriving at a price which the company could afford to accept and which the city could afford to pay.

Your letter suggests that the price named is based on the offer of this Company made in 1909, and upon Judge Farrington's finding in the rate cases, with additions "arrived at for reasons stated below and as a matter of business judgment".

The offer to which you refer was made in November, 1909. It was made for the purpose of bringing to an end a very disagreeable controversy that had existed between the city and the company for many years; to avoid the necessity for additional capital expenditures; and to relieve the company from the defense of important law suits which were then pending. All this litigation has been determined favorably to the company; the capital expenditures which it hoped to avoid have been made, and the conditions now existing are radically different from those prevailing in November, 1909.

So far as the offer is based upon the finding of Judge Farrington as of November 1, 1903, it is only fair to say that he found a value for rate-fixing purposes only, and not for purposes of sale. He expressly said that, in a condemnation proceeding, the examination of value could not be restricted to the water-bearing capabilities of the properties, and further, that the value sought to be ascertained in condemnation proceedings is the market value. It is impossible to tell, from Judge Farrington's opinion, what he considered the value of the property for purposes of sale. In all the rate litigation the city earnestly contended that, for purposes of sale, a different basis of value from that applicable in rate-fixing cases would obtain.

Your offer overlooks very important elements of value which, of necessity, must be considered when a sale is contemplated, and which were not included in Judge Farrington's valuation. He did not allow for reservoir lands not then actually used for reservoir purposes anything beyond the value of those lands for watershed purposes, expressly saying that, when they were used for reservoir purposes, their value for those purposes would attach to them. In determining the

value of our water rights he allowed us only upon our ability to supply thirty-five million gallons per day, which was the quantity the company was then equipped to deliver; and the only fair and legitimate inference to be drawn from the portion of his opinion in which that subject is discussed is, that as the ability of the company to supply water expands, the value of the water rights will correspondingly increase.

Your offer, while admitting that our properties have increased in value, argues that we are not entitled to the increase. We cannot agree to this. The contention is fully answered and refuted by the Supreme Court of the United States in the Consolidated Gas case, and by Judge Farrington in the Water Rate cases. The city cannot, legally, morally, nor in common fairness, expect us to sell any of our properties for less than they would be worth if in the hands of others than the Spring Valley Water Company.

We cannot subscribe to the statement contained in your letter, that investigations of our undeveloped sources have shown that their capacity for a dependable extension of the supply is less than had previously been supposed by city officials and citizens, and by our own officers and stockholders. On the contrary, later and more exhaustive examinations, made by disinterested engineers, have demonstrated the capacity of the undeveloped sources to be greater than ever heretofore claimed by the company.

In accepting Judge Farrington's finding as a starting-point, you must have in mind that valuable reservoir lands were not valued as such; that only a comparatively small part of our water-rights was valued; that no valuation of going concern was included in his total; and that the real properties, herein offered you, have very considerably increased in value since 1903. If you consider these elements in value not included by Judge Farrington and the increase in value since the date to which his valuation relates, we feel that you will have no difficulty in reaching the conclusion that the property we offer you is worth more than the price at which it is offered. We firmly believe that it is less than would have been found had either of the plans, hereinbefore mentioned as having been tentatively proposed by the Advisory Water Committee for the ascertainment of value, been pursued to a conclusion.

What we understand the city desires to acquire is a water supply. The property we offer includes all of the company's holdings which, according to Mr. Freeman's plan, are necessary to provide the city with a complete water works system, and will enable it to proceed at once to meet the demand of consumers and arrange for the largely increased requirements involved in the preparation for, and operation of, the Panama-Pacific Exposition. The property of the company not included in this offer, and which forms no part of Mr. Freeman's plan, has a prospective value that may, in some measure, compensate the stockholders for the sacrifice which, we believe, they would make in selling the property at the price herein proposed.

The offer is made upon the following conditions:

1. The offer is for cash;

2. The offer shall expire on the twentieth day of October, 1912, unless before that date the Supervisors shall have taken the initial proceedings to submit to the voters the proposition to buy the property on the terms herein stated, in which case it shall be in force till January 1, 1913;

3. If this offer is accepted by the necessary two-thirds of the electors, the Board of Supervisors shall, within thirty days thereafter, allow the company to take judgment in all litigation with the city, and the city shall then relieve the company and its sureties from any liability upon the bonds heretofore filed in any litigation between the city and the company; and shall allow the company to withdraw and retain all water rates collected by it since the commencement of the water rate litigation, including the amount of money impounded under order of court;

4. If the offer is accepted through the necessary votes of the people, the purchase must be consummated by March first, 1913. If, at the time of the consummation of the purchase, any instalment of taxes levied and assessed for the fiscal year 1912 shall not be delinquent, the sale shall be made subject to the payment of all such taxes by the City and County, and the City and County shall pay the same;

5. The issued bonds of the company amount to the sum of $20,987,000, and bonds not surrendered must be assumed by the City and County, the face value of any non-surrendered bonds to be deducted from the pur-

chase price, interest coupons to be adjusted as of the date of sale;

6. The capital expenditures made by the company after this date are to be added to the purchase price herein fixed, but the company shall discharge all mortgages (other than the lien of its deed of trust) executed by its grantors covering property in Alameda and Santa Clara Counties, and included in the terms of this offer;

7. At the time the purchase is closed the city is to pay the company all water rates then accrued for water supplied to the city and the company is to collect all rates then due from private consumers, and the city will cause itself to be substituted in the place of the company in all litigation then pending, involving the property offered, other than litigation affecting the validity of ordinances establishing water rates, and assume all future responsibility and expense of such litigation;

8. The company is to convey only such title as it has;

9. If the offer be accepted, water rates to private consumers for the fiscal year beginning July 1, 1912, shall be at least 15% in excess of those established by the ordinance which was passed for the fiscal year beginning July 1, 1910; and the rate for hydrants shall be $2.50 per hydrant per month, and these rates shall be maintained until the consummation of the purchase and payment of the purchase price, and the Board of Supervisors shall enact rates accordingly.

Respectfully submitted,

SPRING VALLEY WATER COMPANY,
By A. H. Payson,
First Vice-President.

A. H. Payson,
Frank B. Anderson,
Edw'd J. McCutchen,
Committee.

ADDENDA

Mayor's Office, San Francisco.
San Francisco, Cal., October 19, 1912.

Spring Valley Water Company, 375 Sutter Street, San Francisco, California.

Regarding the Purchase of Works by the City:—

Gentlemen:—I am directed by the Board of Supervisors of the City and County of San Francisco to make reply to your communication of September 14th, 1912, wherein you propose to sell to the City your properties, excepting lands surrounding Lake Merced, upon the terms mentioned in such communication.

The utility of Lake Merced for emergency water supply throughout the long autumn would be too seriously impaired by diverting so much of the surrounding lands to residential purposes or other purposes inconsistent with the use of the lands for a water supply.

As presently advised, the City authorities cannot see their way clear to recommend any plan of acquiring your properties which involves the elimination of so much watershed, regardless of price.

After opportunity is afforded the City to examine and analyze the inventory and appraisal of your properties made by J. G. White & Co., a copy of which you were, on October 16th, 1912, requested to furnish, it may be possible that some elements may be found having greater value to the Company than to the City, which can be safely excluded, under fair terms, without impairing the value of the plant for a municipal water supply and service.

The Board of Supervisors, as well as myself, are extremely desirous that some satisfactory plan may be arrived at by which your properties may be acquired by the City, and that an amicable adjustment may be made as expeditiously as possible.

The necessities of the outlying districts for the extension of the water mains is urgent. The growth of the City is being retarded for lack of proper water facilities in the unserved sections.

We express the hope that, after further consideration, you will see your way clear to accept the offer submitted to you in our communication of August 9th last. We are convinced that the City's offer is fair to both the Company and the City.

Respectfully yours,
JAMES ROLPH, JR.,
Mayor of the City and County of San Francisco.

San Francisco, Cal., November 13, 1912.

Honorable James Rolph, Jr., Mayor; Percy V. Long, City Attorney; Thomas Jennings, Chairman Finance Committee; Alexander T. Vogelsang, Chairman Public Utilities Committee, and Curtis H. Lindley, Esq., comprising the City Advisory Water Committee, and The Members of the Board of Supervisors of the City and County of San Francisco.

Regarding the Purchase of Works by the City:—

Gentlemen:—A meeting of the Board of Directors of the Spring Valley Water Company was held on the thirteenth day of November, 1912. After giving the subject matter of your letter of October 19th careful consideration, the Board by unanimous resolution directed the Committee to make reply as hereinafter set forth:

We cannot agree in your conclusion that the utility of Lake Merced for emergency water supply "throughout the long autumn" would be too seriously impaired by diverting so much of the surrounding lands to residential purposes, or other purposes inconsistent with the use of the lands for a water supply.

This company is now installing a filtration plant at Lake Merced through which all of the water used from that source will be filtered, and by the use of which this water will be made entirely safe even for domestic purposes. We are supported in this conclusion by the results obtained from the Government filtration plant, which converts the water obtained from the densely populated drainage area of Lobos Creek into a perfectly satisfactory supply for all purposes at the Presidio.

There are many cities furthermore whose water supplies before filtration are not nearly so pure as the waters of the Merced Lakes would be with proper and practicable provisions for their protection, even after the occupation of this drainage area for residential purposes.

The force of these facts as bearing upon the supply for San Francisco is emphasized by the additional fact that the plans of Mr. Freeman do not contemplate the utilization of the Merced Lakes for water supply for San Francisco, except possibly in cases of emergency, as is evidenced by the following quotation from his report (San Francisco Water Supply, page 126):

> "Although these lakes hold 2,500 million gallons when full, which has value as a reserve against some contingency that could hardly occur more often than once in half a century, probably their chief future use will be to beautify a park, and this possibility of raising the flow line should be given attention when laying out any expensive circuit of pleasure roads around the lake."

You state that you and the Supervisors are extremely desirous of reaching some plan by which the properties of this company may be acquired by the City and that an amicable adjustment may be made as expeditiously as possible. We feel that in our letter of September 14th we offered you a plan which completely provides for the necessities of the City so far as the properties of the company are concerned and that the responsibility will rest with you whether you will avail yourselves of the opportunity of acquiring what the City requires in the way of water supply from the Spring Valley Water Company, or whether you will decline to purchase because you cannot, at the same time, and for what we are convinced is an inadequate price, obtain lands which, according to the report of Mr. Freeman, are not at all needed, in addition to the lakes themselves, either in connection with the ordinary water supply of the City, or to provide against emergencies.

You express the hope that, after further consideration, the Company will see its way clear to accept the offer submitted in your communication of August 9th, which you say you are convinced is fair to the Company and to the City.

We cannot consider it fair to ask the Company to surrender lands, which, according to the testimony of the most competent judges of values of real estate, have a present and prospective value which would make the price offered by the City entirely inadequate, solely that the City may hereafter use these lands for park purposes, or for sale by itself at an enhanced valuation, without any need for them as a part of its proposed municipal supply.

The City Engineer has lately reported to your administration that "the City is now very much at a disadvantage in not knowing the real worth" of the property of our company. This report has, in effect, been adopted by the Board

of Supervisors. In view of this action, it would appear that your administration does not feel that it is even now in possession of all of the facts which would enable it to arrive at a fair valuation of the property. In our letter of September 14th, we expressed regret that one of the two plans proposed to us by the City Advisory Committee for determining the value of the property of the Company (and approved by us) was not pursued to a conclusion, and we suggest now that some form of arbitration under which due recognition could be given to the rights of the stockholders to the enhanced value of their real estate holdings, not needed for water supply purposes, would be the most satisfactory way of arriving at a fair adjustment of the differences between us.

In conclusion the Board of Directors can only repeat the reply conveyed to you in its letter of September 14th, declining the offer contained in your letter of August 9th.

Respectfully submitted,

SPRING VALLEY WATER COMPANY,

By A. H. PAYSON,

First Vice President.

A. H. PAYSON,
FRANK B. ANDERSON,
EDW'D J. MCCUTCHEN,
Committee.

UNAVAILING EFFORTS OF SPRING VALLEY WATER COMPANY TO OBTAIN CONCLUSIONS OF ENGINEERS GRUNSKY, HYDE AND MARX ON WATER PRODUCT OF TRANSBAY SOURCES

San Francisco, July 10, 1912.

John R. Freeman, Esq.,
St. Francis Hotel, San Francisco, Cal.

My Dear Mr. Freeman: Heretofore the Spring Valley Water Company has felt that it was its duty to place before you, as the representative of the City, any information that the company possessed in reference to the water supply of San Francisco. We feel that this attitude should be reciprocal, and that any information that the City possesses should be placed before us. Will you be good enough to inform me if this will be your attitude.

Very sincerely yours,
W. B. BOURN,
President.

(Letterhead of John R. Freeman.)

San Francisco, July 10th, 1912.

William B. Bourn, President,
Spring Valley Water Company,
San Francisco, Calif.

My Dear Mr. Bourn: I have just received your note. It puzzles me because ever since I came into this case I have tried in every way to promote mutual understanding on water supply matters between the City and the Company, and have repeatedly urged on all with whom I came in contact my belief that the City and the Company should work toward a friendly understanding and a purchase, and I have not hesitated to make plain to Mr. Eastman the lines toward which my conclusions were tending on various questions as they have arisen.

I therefore hasten to reply to your note, although Judge Lindley and the Mayor are both absent, and I would like to talk with them and obtain a fuller expression of their views and desires. Meanwhile, my own understanding of the matter is that both parties are desirous of getting together, and that the best means of accomplishing this is for each to willingly show to the other whatever facts he has bearing on the value and utility of the works. It is not to be expected that we will all think alike, but we can at least respect each others' opinions and can recognize that in our own minds, as possibly in that of those on the other side, some prejudice is always liable to exist of which the man who possesses it may be wholly unconscious, and if you find me prejudiced in interpreting your data, it will be unconscious.

Sincerely yours,
JOHN R. FREEMAN.

San Francisco, July 10, 1912.

John R. Freeman, Esq.,
St. Francis Hotel, San Francisco.

My Dear Mr. Freeman: I fear you misunderstood the purport of my note. Allow me to assure you that we greatly appreciate your personal feelings in this matter, and I am sure we will be mutual in our respect for each other's opinions.

The reason for my note was that it was reported to me that Messrs. Grunsky, Marx and others had reported on the Alameda System, and the question arose whether those reports would be available to us. I am expecting to leave town next Tuesday on an indefinite absence, and I therefore wrote my note to you, having in mind these reports.

Since dictating the above, I have re-read my note to you of this morning, and I apologize for sending a note that was open to misconstruction. We fully appreciate your personal attitude in this matter, and my note was hurriedly called forth, as explained above.

Upon the return of the Mayor, would you be

good enough to let me know if the Grunsky and other reports when presented, will be available to the Company.

Very sincerely yours,

W. B. BOURN,

President.

San Francisco, California, August 19th, 1912.

Curtis H. Lindley, Esq., Chairman, Advisory Water Committee, Mills Building, San Francisco, Cal.

Dear Sir:

The letter addressed to the Spring Valley Water Company dated the 9th day of August and signed by the members of the Advisory Committee and by members of the Board of Supervisors, has been referred to us by the Board of Directors of the Company. It may aid us if you will furnish us with the following information, namely:

1—Your valuation of the Lake Merced property owned by the Company;

2—Mr. Freeman's valuation of "going concern";

3—Reports of Messrs. Grunsky, Marx and Hyde on the run-off of water yield of the trans-bay sources of the Company. If the engineers named did not make a formal report, we shall be glad to have the results of the investigations in whatever form you may have them.

Yours truly,

EDW. J. McCUTCHEN,
F. B. ANDERSON,
Committee.

San Francisco, August 21, 1912.

Messrs. Edward J. McCutchen and F B. Anderson, Committee of Spring Valley Water Company.

Gentlemen:

Your favor of the 19th inst., addressed to me as Chairman of the Advisory Water Committee, has been submitted to the Committee and I have been instructed to reply as follows:

1. As to our valuation of the Lake Merced property, we adopted Judge Farrington's finding in this behalf. On page 77 of the printed opinion, you will find his valuation of property in use to be $25,771,984, included in which is the Lake Merced property, valued at $3,382,600. You will observe that in our letter of August 9th we have made use of this total valuation as a factor in making up the offer of $38,500,000.

2. The method of valuing the indeterminate factors entering into the valuation of the property as a whole is set forth in Mr. Freeman's letter to the Mayor, copy of which you have. The result reached is deemed by Mr. Freeman to be fair and just, and the City officials concur.

3. With reference to the report of Messrs. Grunsky, Marx and Hyde, it has not as yet been completed. We are advised that as yet there has been no concurrence of opinion as to the result of their inquiry. Mr. Freeman has been from time to time informed of their progress. Before this letter was written, we had an interview with Mr. Grunsky who has explained the status of the investigation and the different methods by which they have attempted to reach a result. Mr. Freeman has stated to us that after considering the work of these gentlemen, as described to him by Mr. Grunsky, on August 19, 1912, he sees no reason to change or alter his recommendations as set forth in his letter to the Mayor of August 9, 1912.

Sincerely yours,

CURTIS H. LINDLEY,
Chairman Advisory Water Committee.

San Francisco, October 25, 1912.

Hon. James Rolph, Jr., Mayor,
New City Hall, San Francisco, Cal.

Dear Sir:

On the 10th of July, 1912, Mr. Bourn, as president of the Spring Valley Water Company, addressed to John R. Freeman a letter reading as follows:

> "Heretofore the Spring Valley Water Company has felt that it was its duty to place before you, as the representative of the City, any information that the Company possessed in reference to the water supply of San Francisco. We feel that this attitude should be reciprocal, and that any information that the City possesses should be placed before us. Will you be good enough to inform me if this will be your attitude?"

To this letter Mr. Freeman replied on the same date. From his reply I quote the following:

> "I * * * hasten to reply to your note, although Judge Lindley and the Mayor are both absent, and I would like to talk with them and obtain a fuller expression of their views and desires. Meanwhile, my own understanding of the matter is that both

parties are desirous of getting together and that the best means of accomplishing this is for each to willingly show to the other whatever facts he has bearing on the value and utility of the works."

After the receipt of the letter signed by yourself and the other members of the Advisory Water Committee and by seventeen members of the Board of Supervisors, dated August 9th, 1912, addressed to the Spring Valley Water Company, that Company, through its negotiating committee, sent to the Advisory Water Committee a letter requesting certain information, including:

"3. Reports of Messrs. Grunsky, Marx and Hyde on the run-off or water yield of the transbay sources of the Company. If the engineers named did not make a formal report, we shall be glad to have the results of their investigations in whatever form you may have them."

To this we received a reply, under date of August 21, 1912, from which I quote:

"3. With reference to the report of Messrs. Grunsky, Marx and Hyde, it has not as yet been completed. We are advised that as yet there has been no concurrence of opinion as to the result of their inquiry. Mr. Freeman has been from time to time informed of their progress. Before this letter was written, we had an interview with Mr. Grunsky who has explained the status of the investigation and the different methods by which they have attempted to reach a result. Mr. Freeman has stated to us that after considering the work of these gentlemen, as described to him by Mr. Grunsky on August 19, 1912, he sees no reason to change or alter his recommendations as set forth in his letter to the Mayor of August 9, 1912."

Since the last named date we have, from time to time, inquired whether the report of Messrs. Grunsky, Marx and Hyde had been prepared and signed. I was informed by Judge Lindley some time ago, in response to an inquiry addressed to him, that two reports, signed by those engineers, or some of them, had been delivered to him, and that he had sent them to you. He also told me, as I recall, that you had sent one copy to Mr. Freeman and one copy to Mr. Long.

Last Monday (October 21st) Mr. Cyril Williams informed Mr. Behan that he had received a copy of the report from Mr. Long's office, and that he then had it in his possession. On the same day I called Mr. Long on the telephone and told him what Mr. Williams had told Mr. Behan, and asked him who had the authority to direct Mr. Williams to furnish us with the report, or a copy of it, and he replied that such authority was vested in the City Engineer. Thereupon I immediately called upon Mr. O'Shaugnessy, the City Engineer. He said he had never seen the report and did not know that it was in Mr. Williams' possession. I then, in the presence of Mr. O'Shaughnessy, and in his office, called Mr. Long on the telephone and had a conversation with him, all of which, so far as my end of it was concerned, was carried on in Mr. O'Shaughnessy's hearing. I asked Mr. Long, over the telephone, if Mr. O'Shaughnessy had authority to direct Williams to furnish me with the report, or a copy of it, to which he replied in the affirmative. I then said to Mr. O'Shaughnessy, so that Mr. Long, at the other end of the telephone line, could hear it, "Mr. Long says that Williams is under your orders, and that you have authority to direct him to let me have the report, or a copy of it." I then passed the telephone to Mr. O'Shaughnessy, who said to Mr. Long, in my presence, that he had not seen the report and did not know, until informed by me, that Williams had it. After the telephone conversation with Long was finished, I said to Mr. O'Shaughnessy that I was going to Los Angeles and would return Wednesday, at which time I would call upon him for the report. I asked him if he would, in the meantime, endeavor to obtain it for me, to which I understood him to reply in the affirmative.

I called Mr. O'Shaughnessy on the telephone yesterday (Thursday, October 24th), and asked whether he could furnish me with the report, to which he replied that I would have to see the City Attorney. Thereupon I called you on the telephone, told you of my efforts to get the report, and read you the correspondence between Mr. Bourn and Mr. Freeman, which I have quoted.

As evidence that the Spring Valley Water Company has lived up to the spirit of the understanding set forth in the Bourn-Freeman correspondence, I call attention to the following paragraph found in the report of Mr. Freeman, entitled: "San Francisco Water Supply," dated August 29th, 1912, viz.:

"I desire to record my appreciation of the courtesy of the officials of the Spring Valley Water Company in rendering to me, and to those working with me for the City, the opportunity to examine their records, and I desire to acknowledge the promptness with

which they have supplied the data that I have asked for."

It is my understanding that, in our telephonic communication of yesterday afternoon, you told me you would communicate with the City Attorney and that I would hear from you in the course of half an hour. I did not hear from you, however, and assume that the failure was due to press of official business, as I read in the morning papers you were busily engaged yesterday and until late last night in preparing an official paper.

I think you must appreciate that this report cannot be denied us except in violation of the spirit of the understanding reached between the representatives of the City and the representatives of the Company for the exchange of information, and I think you also appreciate that, if we are to have it at all, we should have it without any further delay.

I shall esteem it a favor if we may have your good offices in obtaining it.

Yours very truly,
EDW. J. McCUTCHEN,
Counsel for Spring Valley Water Company.

San Francisco, October 31, 1912.

Hon. James Rolph, Jr.,
Mayor,
New City Hall,
San Francisco, Cal.

Dear Sir:

On October twenty-fourth I had a telephonic conversation with you in relation to the report of Messrs. Grunsky, Marx and Hyde on the run-off or water yield of the transbay sources of the Spring Valley Water Company. On October twenty-fifth I wrote you a letter on the same subject, to which you responded in writing on that date that you would reply to my letter as soon as you could.

I am still without a reply from you, and shall esteem it a favor if you will let me hear from you today. As you know, the Spring Valley Water Company is required to make whatever showing it desires to make before the Board of Army Engineers not later than November 1, 1912.

Yours truly,
EDW. J. McCUTCHEN,
Counsel for Spring Valley Water Co.

WESTERN UNION TEL. COMPANY.
NIGHT LETTER.

San Francisco, Oct. 30, 1912.

John R. Freeman,
Banigan Building, Providence, R. I.

May we have by return telegram your authority or consent to obtain a copy of the Grunsky Hyde Marx report upon the flow of Alameda Creek. Will greatly appreciate any consideration you may give this request.

S. P. EASTMAN.

Mayor's Office,
San Francisco.

San Francisco, Cal., November 1st, 1912.

Mr. Edward J. McCutchen,
Counsel for Spring Valley Water Co.,
Merchants Exchange Building,
San Francisco, Cal.

Dear Sir:

Replying to your communications of the 25th and 31st ultimo, I beg to say that City Attorney Long needs the only Report he has, and has same under review and study; and I am unable to furnish you with a copy.

Very truly yours,
JAMES ROLPH, JR.,
Mayor.

JR-CM

B-M'C-S

San Francisco, November 1, 1912.

Hon. James Rolph, Jr.,
Mayor,
New City Hall,
San Francisco, Cal.

Dear Sir:

I beg to acknowledge receipt of your letter of this date. It is possible that Messrs. Grunsky, Marx and Hyde have a copy of their report referred to in your letters of October twenty-fifth and November first, in the latter of which you say that the City Attorney needs the only report he has, and you are unable to furnish me with a copy.

I would not apply to Messrs. Grunsky, Marx and Hyde for a copy, or for the privilege of inspecting a copy if they have one, without your permission. I write, therefore, to ask if you will let me know, without delay, whether I have your authorization to ask them to allow me to in-

spect the report, if they have a copy of it in their possession.

Yours truly,
EDW'D J. McCUTCHEN,
Counsel for the Spring Valley Water Co.

Mayor's Office,
San Francisco.
San Francisco, Cal., November 1st, 1912.
Mr. Edward J. McCutchen,
Counsel for Spring Valley Water Company,
Merchants Exchange Building,
San Francisco, Cal.

Dear Sir:

Your favor of even date was delivered to me at 4:40 this afternoon in the chambers of the Board of Supervisors, while I was presiding over a meeting of that body. The Board has just adjourned at 5:30 p. m., and I hasten to make you a reply as requested, "without delay."

I do not feel, at this time, that it is within the scope of my authority to give you the authorization you ask in your communication under acknowledgment.

Since writing you this morning, I have been informed by the City Attorney that the copy of the Report which I sent to him was at that time delivered by him to Cyril Williams, Jr., and that this copy of the Report is still in the possession of Mr. Williams.

Very truly yours,
JAMES ROLPH, JR.,
JR-CM Mayor.

P. S.—6. p. m. Your messenger has just called for an answer, and I am handing him this reply.

ADDENDA

San Francisco, Cal., November 2, 1912.

Hon. James Rolph, Jr., Mayor, City and County of San Francisco, San Francisco, California.

Dear Sir:—

Your letter of yesterday makes it necessary for me to write you further regarding the Marx, Grunsky and Hyde report.

When I telephoned you on October 24th of my ineffectual attempts to get the report, you replied that you could not understand why I was "stalled" in my efforts to obtain it. In your letter of yesterday you say it is not within the scope of your authority to give my company permission to apply to Messrs. Marx, Grunsky and Hyde for an inspection of their report. I am in doubt as to the meaning of your letter. We have consulted you in this matter because you are the head of the municipal administration. Am I to understand that the power to authorize the engineers named to allow the desired inspection rests with some representative of the municipality other than yourself? If so, I shall be glad if you will immediately furnish me, in writing, with the name of such representative.

Yours truly,

E. J. McCutchen,

Counsel for Spring Valley Water Company.

Mayor's Office

San Francisco.

San Francisco, Cal.

Nov. 2, 1912.

Mr. E. J. McCutchen, Counsel of Spring Valley Water Company, Merchants Exchange Building, San Francisco.

Dear Sir:—

Replying to your letter of even date, I have to say that, inasmuch as you rely upon an understanding with Mr. Freeman for the delivery to you of all data secured by the City, I have wired Mr. Freeman, concerning your request, and he has wired me, as follows:

"Received telegram from Eastman Spring Valley asking my consent to delivery of Hyde Marx Grunsky report immediately. I have replied as follows to Eastman paragraph delayed by absence yesterday and to-day from earlier answering your telegram decision on delivery Grunsky Marx Hyde report properly rests with City Attorney but I should advise him to delay delivery until I have opportunity to review further and confer with authors about assumption regarding data and theories of estimating which from present information I believe surely wrong and misleading. I believe that premature distribution of erroneous computations is not helpful and that it is far better for City and Company to unite on some new first class scientific measurements of Alameda flood flow during present rainy season for obtaining new rating table giving quantities pertaining to various heights over Sunol and Niles dams meanwhile setting scales at points of original observation and restoring obstruction near Niles manhole to former condition.

"John R. Freeman."

I am astonished at the tenor of your letter of even date, if the company or yourself had been in possession of Mr. Freeman's telegram to Mr. Eastman, quoted herein. I received your letter by messenger, at 11:55 a. m. I received Mr. Freeman's telegram when I reached the office early this morning.

As Mr. Freeman is in charge of the City's presentation of Hetch Hetchy matters, I must be governed by his advice.

Yours very truly,

James Rolph, Jr.

Mayor.

San Francisco, November 4, 1912.

Hon. James Rolph, Jr., Mayor, New City Hall, San Francisco, Cal.

Dear Sir:

I have your letter of November second, in which you express astonishment at the tenor of my letter of the same date "if the company or yourself (myself) had been in possession of Mr. Freeman's telegram to Mr. Eastman." I was out of town when your letter of November first was received at my office. It was read to me over the telephone late that night. The next morning I dictated, over the telephone, the an-

swer to it which was sent to you. After the answer was dictated—but I am unable to say whether before it was delivered to you—Mr. Eastman read to me, over the telephone, the telegram which he received from Mr. Freeman.

Mr. Eastman telegraphed Mr. Freeman without consultation with me. I am frank to say that if I had been advised of the contents of Mr. Freeman's telegram before dictating my letter to you of November second, I would not have changed the phraseology of the letter. The telegram said the decision on the request we had made rested with the City Attorney. The City Attorney, whose statement we were certainly authorized to accept with reference to his authority in the premises, had previously told us, in effect, that it rested with the City Engineer to allow us an inspection of the report. We applied to the City Engineer and failed to get any results, whereupon we appealed to you. After correspondence with you on the subject, you told me it was not within the scope of your authority to authorize the inspection which we requested. You had never told us that Mr. Freeman's recommendation or decision on the subject would be conclusive, and I do not know why we should have assumed that it would. You did not tell us who was authorized to act in the matter and, inasmuch as the City Attorney had previously informed us, in substance, that it was not under his control, but under that of the City Engineer and, inasmuch as the City Engineer had sent us back to the City Attorney, I do not see that there was anything for us to do, after your letter disclaiming authority, but to ask you who did have authority in the matter. Furthermore, I do not see how the situation, in this regard, was, or is in any way affected by Mr. Freeman's telegram.

We can put only one interpretation on the attitude of the representatives of the city in the light of this telegram. Read between the lines, the telegram clearly shows, we think, that the report does not sustain the claims which Mr. Freeman is now asserting before the Secretary of the Interior in behalf of the city. This is a report prepared by engineers of the city's selection, acting under instructions of Mr. Freeman, and yet, we take it from your last letter, we are not to be permitted an inspection of it.

When, from time to time, representatives of the city—particularly Mr. Freeman—have requested of us specific information, we have not stopped to consider what the effect of its production upon our case would be, but have, in all instances, complied—and, as Mr. Freeman says, promptly complied—with the requests made. Inasmuch as we feel as we do, it would be lacking in candor not to say that the refusal, under the circumstances detailed, to permit us to have a copy of this Grunsky-Marx-Hyde report convinces us that the city has not met us in the same spirit with reference to the information under its control. The attitude of its representatives leaves but one course open to us, and that is to demand that the city produce the report at the hearing before the Secretary of the Interior in Washington. We make this demand now, in order that the city's representatives may be prepared to produce the report at the hearing if the Secretary of the Interior or the Advisory Board of Army Engineers think it proper evidence to go into the record.

Yours truly,

Edw'd J. McCutchen,

Counsel for Spring Valley Water Company.

EXECUTIVE DEPARTMENT

SPRING VALLEY WATER COMPANY

375 Sutter Street

San Francisco, Cal., October 31, 1912.

To the President and the Board of Directors
of the Spring Valley Water Company.

Before closing the report upon the "Future Water Supply of San Francisco from the Conservation and Use of Its Present Resources" for presentation to The Honorable The Secretary of the Interior and his Advisory Board of United States Army Engineers, I desire to bring to your attention and to make record of a grateful appreciation so deserving to the engineers, geologists and specialists whose works appear in the report under their respective names: Messrs. Wm. Muholland, J. B. Lippincott, H. M. Chittenden, A. O. Powell, George G. Anderson, J. C. Branner, A. C. Lawson, J. N. Le Conte and C. H. Lee; and Messrs. H. Schussler, F. C. Herrmann, F. W. Roeding, J. J. Sharon, T. W. Espy, I. E. Flaa and H. Monett, engineers of the staff of the Spring Valley Water Company.

It is a source of the highest gratification that so great an amount of this important work was contributed by employes of the company. The great task of properly assembling the text of the report, assisting in editing it and the many other duties incident to a finished work, and requiring skill, judgment and perseverance, were met by members of our staff, Messrs. John E. Behan and G. A. Elliott. To them is due high credit and I desire to specially bring before you notice of their work which has been of decided merit.

I cannot close without a full acknowledgment of gratitude to the pressmen, compositors and other faithful employes of Mr. Andrew Y. Wood. Their work has been done under much pressure; the many trying difficulties encountered have meant to them only greater effort rendered in a spirit of loyalty which is a tribute to their manager, Mr. Wood.

I commend to your consideration that this letter be spread upon the minutes of the company as a record of appreciation to those who have assisted in the work of this report.

Respectfully,

S. P. EASTMAN,

Vice-President and Manager.

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